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HEAT STRESS ILLNESS IN A MECHANIZED INFANTRY BRIGADE DURING SIMULATED COMBAT AT FORT IRWIN

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

MAY 1994

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Heat Stress Illness in a Mechanized Infantry Brigade During Simulated Combat at Fort Irwin

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This report provides environmental temperature data and descriptive heat stress casualty statistics for an active duty mechanized infantry brigade during a three week training rotation, in August 1992, at the US Army National Training Center (NTC), Fort Irwin, California. Mean and standard deviation for noontime ambient temperatures were: 104.3 ± 6.0 °F (dry bulb), 129.0 ± 7.5 °F (black globe), 71.4 ± 2.6 °F (wet bulb), 86.2 ± 3.3 °F (WBGT). Between 13-19 August (17 days inclusive), 520 soldiers were evaluated at the brigade medical company treatment tent with a mean of 31 ± 16 per-day (range: 14 - 58). Of these 520 patients, 90 had heat stress illnesses for an average of 5 ± 3 heat casualties per day (range: 0 - 13). Heat stress casualties comprised 20 ± 13% of the total number of daily patients (range: 0 - 48%). The rate of heat stress illness for the brigade was relatively low despite high WBGTs and rapid paced training scenarios. The NTC is recommended as a location for further USARIEM research on the practical military effects of hot-dry heat stress on soldiers' health and performance as well as delineating the logistical requirements that heat related casualties impose on supporting medical units.

Heat illness, heat exhaustion, thermal stress, desert warfare training, medical operations.

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TECHNICAL REPORT

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by

Matthew J. Reardon, MAJ-MC

May 1994

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

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EXECUTIVE SUMMARY

This technical report provides environmental temperature data and descriptive heat stress casualty statistics for an active duty mechanized infantry brigade during a three week training rotation, in August 1992, at the US Army National Training Center (NTC), Fort Irwin, California. A portable digital wet bulb globe temperature (WBGT) recorder was utilized to obtain environmental temperatures within the NTC combat training area. Additional WBGT readings were obtained from the analog WBGT device maintained at the Fort Irwin's Preventive Medicine Activity. Heat stress casualty data were obtained from the medical company supporting the brigade. Mean and standard deviation for noontime ambient temperatures were: 104.3 ± 6.0 °F (dry bulb), 129.0 ± 7.5 °F (black globe), 71.4 ± 2.6 °F (wet bulb), 86.2 ± 3.3 °F (WBGT). Between 13-19 August (17 days inclusive), the total number of soldiers evaluated at the brigade medical company treatment tent was 520 with a per-day mean of 31 ± 16 (range: 14 - 58). Of these 520 total patients, 90 had heat stress illnesses for an average of 5 ± 3 heat casualties per day (range: 0 - 13). Heat stress casualties comprised 20 ± 13 % of the total number of daily patients (range: 0 - 48 %). There were several cases of heat stroke but these individuals recovered without complications. The rate of heat stress illness for the brigade was relatively low despite high WBGTs and rapid paced training scenarios. This report provides USARIEM with a preliminary characterization of the environmental temperatures and an estimate of the typical heat stress casualty rate expected for a active duty mechanized infantry brigade deployed for desert warfare training at the NTC. The NTC is recommended as a location for further USARIEM research on the practical military effects of hot-dry heat stress on soldiers' health and performance as well as delineating the logistical requirements that heat related casualties impose on supporting medical units.

INTRODUCTION

This technical report provides environmental temperature data and descriptive heat stress casualty statistics for the 3rd Brigade, 24th Mechanized Infantry Division during a three week training rotation in August 1992 at the US Army National Training Center (NTC), or synonymously, the Armor and Desert Training Center, Fort Irwin, California. This highly experienced active duty brigade was deployed to the NTC from Fort Benning, Georgia.

A portable digital wet bulb globe temperature (WBGT) recorder was utilized to obtain environmental temperature data within the NTC combat training area. Additional WBGT readings were obtained from records maintained at the Fort Irwin's Preventive Medicine Activity. Heat stress casualty data were obtained from the 3rd Brigade medical records. This information was analyzed to provide USARIEM with a preliminary characterization of the summertime temperatures at the NTC as well as an estimate of the heat stress casualty rates for an active duty Army brigade deployed there for desert warfare training.

The NTC is a major Army combat training center in a thermally stressful desert environment. There is reason to believe that it could be a good location for USARIEM to establish a field research site to permit the systematic study of the practical military effects of hot-dry heat stress on modern military units. Such research would emphasize determining the extent to which the hot desert weather adversely affects soldiers' health and performance. Additionally, the logistical demands that heat stress casualties impose on supporting medical units could be quantitated. Although USARIEM has, and continues to conduct field studies at locations such as Fort Bliss, White Sands, Dugway Proving Grounds, and Camp LeJeune, no previous USARIEM reports have described the Fort Irwin combat training environment, or its impact on soldier health and performance.

Numerous landmark studies of the physiologic responses of soldiers to the hot-dry desert climate were conducted during World War II in the Army's desert maneuver area near Blythe California several hundred miles south of the NTC between the Salton Sea lake in California and Yuma Proving Grounds in Arizona (Adolf, et al., 1947). However, the extent to which heat stress is a problem in today's largely mechanized units utilizing different technology and tactics has not been well characterized. This report attempts to provide contemporary but preliminary data with regard to this issue. As will be seen, the data in this report are descriptive and not sufficient in extent for complex statistical analysis. Further research would be required to allow analysis such as multiple regression on the many possible factors that might predict the occurrence of heat stress casualties in complex combined arms operations. It is hoped that these data can be augmented by future, more extensive, USARIEM research studies or epidemiologic data collection efforts at the NTC.

Fort Irwin is a one thousand square mile US Army combined arms desert warfare training facility in the Mojave desert of southern California (see Bolger, 1986, for an in-depth description of the NTC and a detailed narrative describing the simulated combined arms warfare). Tenant units at Fort Irwin provide support to US Army active duty, reserve, and national guard units that rotate through Fort Irwin's Armor and Desert Training Center. Fort Irwin is located thirty seven miles north of Barstow California and is an equal distance south of Death Valley. A map of Fort Irwin's location in Southern California is provided in Appendix A. The main base area is several hours driving distance from Los Angeles to the west and Las Vegas to the east. Fort Irwin is part of San Bernardino County California. The terrain at Fort Irwin is characterized by dry plains with light brown to tan dusty sand interrupted by scattered, sharply defined, mountains. Rapid runoff of rainwater from the occasional heavy thunderstorms have, over the years, created numerous wadis in the plains between the mountains. Wadis are undulating depressions carved out in the soft earth by water erosion (Clegg, 1992). The wadis are sufficiently large terrain features that they are often exploited for concealment by tanks, other vehicles, and encampments during the simulated combat operations. Vegetation in the NTC areas primarily consists of scattered waist-high brush. Wildlife such as hares and coyotes are prevalent, particularly during night hours.

Soldiers and most weapon systems used in the NTC simulated warfare areas utilize the Multiple Integrated Laser Engagement System (MILES). There are three main components in MILES . The first component is the battery powered, eye-safe, infrared laser attached to, and aligned with, a rifle or gun barrel. A small recoil sensor causes the laser to generate a short encoded pulse train for each blank or training round fired. These pulse trains are encoded with information that identifies the type of weapon system. The encoded laser pulses substitute for real bullets, rockets, and other projectiles. The second MILES component is an array of small light weight laser sensors that can sense and decode the laser pulse trains. The third component is the analysis and indicator system that determines direct and indirect hits. The electronic components associated with the laser detectors decode the pulses and determine whether the individual or vehicle can be disabled by the weapon system that sent the pulses. If a hit is lethal the receiver's MILES laser is inactivated and a rotating yellow lamp or alarm is activated. Rules of engagement during simulated combat at the NTC usually specify that soldiers who are hit or are in vehicles which are hit by MILES lasers become simulated casualties and must be evacuated through the supporting field medical units before they can be returned to their unit to continue in the scenario. Soldiers carry with them casualty cards in the event they are hit in a MILES engagement. These casualty cards are small preprinted Graphic Training Aids (GTA 8-11-5) that assign soldiers an injury or disease and designate whether they will be a liter case or ambulatory. The casualty card also gives the soldier brief acting instructions to facilitate the medical simulation as well as salient descriptive information for medical personnel to respond to.

METHODS

Arrangements were made with the assistance of the Division and Brigade Surgeons to accompany the 3rd Brigade's Medical Company to the field at the NTC. Heat casualty incidence data were obtained from the 3rd Brigade's 324th Forward Support Battalion's (FSB) Medical Company patient sign-in and disposition log, patient medical records, and on-site observations. Additional heat stress casualty data were obtained from emergency room (ER) treatment records at Fort Irwin's Weed Army Community Hospital (WACH) for those soldiers who were evacuated

directly from the field to the WACH ER (Zaloznick, et al., 1993). To preserve confidentiality, patient identifiers such as names and social security numbers were not recorded.

Environmental temperature data were obtained by use of a battery powered portable programmable temperature recording device (Metrosonics HS-371 WBGT datalogger, see product information sheets in Appendix B). This device recorded shaded dry bulb, wet bulb, and six inch black globe temperatures every ten minutes. These temperatures along with the calculated wet bulb globe temperature (WBGT) were downloaded onto a portable computer for subsequent graphing and analysis using spreadsheet and statistical software. Additional WBGT data were obtained from the Fort Irwin Preventive Medicine (PM) service situated in a small building across the street from the WACH in the main post area. The PM personnel maintained an outdoor Stortz analog WBGT meter on a tripod. PM technicians recorded the WBGT in a notebook periodically during the day.

US Army recommendations for modulating activity levels and duration are based on where the ambient WBGT falls with respect to specific WBGT intervals defined as heat stress categories. These heat stress categories and corresponding WBGT intervals are as follows (see table 2-3, FM 21-10-1, 1989):

Heat stress condition/category	WBGT range °F
1	78-81.9
2	82-84.9
3	85-87.9
4	88-89.9
5	90+

Table 1: WBGT heat stress levels

RESULTS

ENVIRONMENTAL

The weather was hot and dry with clear skies and intense solar radiation. (For a comparison with meteorologic data at Ft. Bliss during August 1991 see: Santee, et al., 1992). From 13-20 August, day and evening WBGT and component temperatures were recorded every ten minutes using a Metrosonics HS-371 WBGT datalogger. Mean and standard deviation for noontime ambient temperatures were104.3 ± 6.0 °F (dry bulb), 129.0 ± 7.5 °F (black globe), 71.4 ± 2.6 °F (wet bulb) , and 86.2 ± 3.3 °F (WBGT) . Calculated humidity was, on average, between 10-20%. The highest WBGT was slightly over 90 °F. Because of the high evaporative cooling capability of the environment, the WBGT usually did not exceed heat stress category 4. Figure 1 below is the frequency distribution of the daily maximum WBGT heat stress category. It indicates a symmetric distribution about category 3 with a standard deviation of 1.

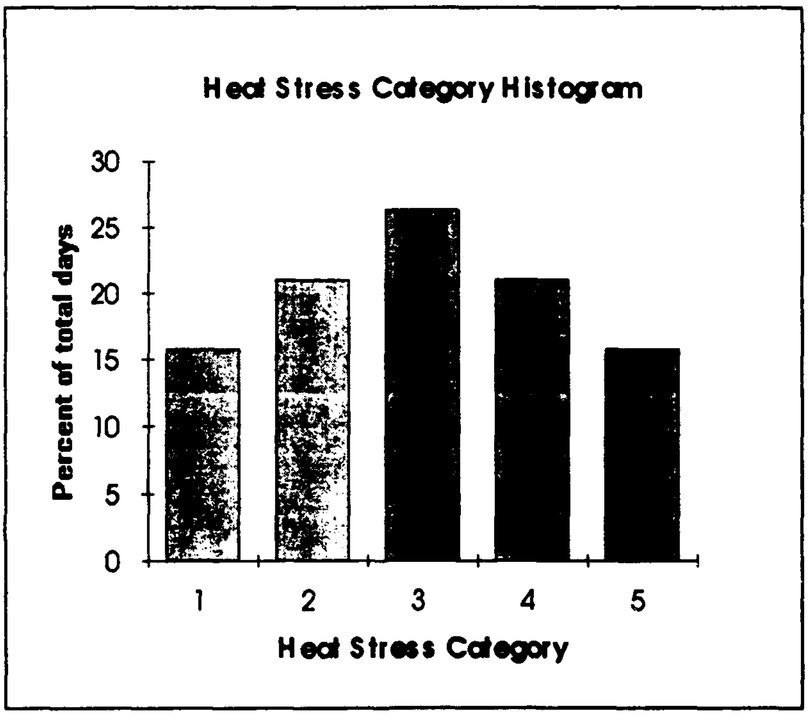


Figure 1: Frequency distribution of daily maximum WBGT heat stress category

Temperature readings from the Metrosonics datalogger were compared to those obtained from the medical company's Stortz WBGT device (which was not utilized by the medical company for environmental monitoring). For a set of six midday readings it was found that this particular Stortz device gave higher readings (0.2 °F dry bulb, 2.8 °F wet bulb, and 2.0 °F WBGT) than simultaneous readings from the Metrosonics device.

Spot measurements of midday sandy soil surface temperatures taken in the field with a pocket industrial thermometer ranged from 128-146 °F.

MISCELLANEOUS OBSERVATIONS

Field hygiene was an intermittent problem during the field exercise. There were fixed latrine, shower, and laundry facilities in the main post bivouac area (appropriately referred to as the "Dust Bowl" because of the paucity of vegetation and ubiquitous sand and fine dirt) . In the field, however, units relied on local contractors to transport, move, and maintain portable toilets. For the first 2-3 days, and for a number of days interspersed during the remainder of the three weeks in the field, no portable toilet facilities were available for the Medical Company. Because the prompt arrival of the portable toilets was anticipated, the medical unit did not establish a field latrine. Other units in the brigade had similar problems. Without enclosed latrine facilities, privacy for toileting was almost impossible to obtain during daylight hours because the surrounding vegetation was so sparse and short. During these intervals, unit members resorted to the expedient of digging "catholes" in unmarked locations about unit perimeters using whatever means they could to obtain a modicum of privacy. The impression was that this situation caused soldiers to withhold water consumption in order to minimize the need to urinate. This may have contributed to what was perceived to be an increased rate of urinary tract infections (UTIs), particularly among female soldiers, during these lapses in availability of adequate field latrines. These UTIs were often accompanied by painful bladder spasms that had to be discerned from heat cramps of the abdominal wall muscles as well as other conditions. Eventually the latrine problem was resolved, hand washing stations established, and a tent with "Australian" showers was set

up. Implementation of these standard hygienic measures resulted in noticeable improvement in the comfort and morale of unit soldiers.

Potable water was obtained from the Class I supply point maintained by Alpha Company of the brigade's 324th Forward Support Battalion (FSB). The medical company area had two 400-gallon "Water Buffaloes" . As alternatives to the 36-gallon Lyster bag, civilian-style water coolers of various sizes and colors were ubiquitous. Water was cooled with bags of ice distributed by brigade supply at a rate, initially, of 13 lbs/soldier/day but subsequently increased to 17 lbs/soldier/day. Priority for ice supply went to the combat units. Since uncooled drinking water averaged at least 100 °F during the day, it was not surprising that the troops placed a great deal of emphasis on availability of ice.

Intravenous (IV) fluids, used primarily to treat troops brought to the treatment tent for heat related illnesses, were initially cooled by use of a field blood bank refrigerator. After a few days, however, the refrigerator became inoperative and IV fluids were subsequently maintained and infused at near ambient temperature. On one occasion the measured temperature of a liter of Ringers Lactate (RL) was found to be 106 °F. In general, is not considered optimal to be infusing (or drinking) fluids that are above a soldier's core temperature particularly in the face of suspected heat related disorders. Based on spot measurements, canteen water and IV fluid could have been cooled during the day by evaporation to at least 80 °F. Canteen evaporative cooling could have been accomplished by keeping the canteen cover and inner pile wetted. IV bags could have been cooled by keeping them covered with a wetted cloth. Wet bulb temperatures represented the theoretically lowest possible temperatures obtainable (65-75 °F) using evaporative cooling methods. The general impression was that evaporative cooling of potable and medicinal fluids was probably not utilized to the extent that it could have been. It is possible that more aggressive use of evaporative cooling would have mitigated some of the heat stress-related problems. On the other hand, extensive use of evaporative cooling would have increased water supply requirements, perhaps significantly.

On 11 August a National Guard light infantry company attached to the Brigade moved out at about 0530 on a road march toward an objective. They started with 2-quarts/soldier of water and were carrying combat loads (up to 70 lbs). Water resupply was planned for but the water tankers in the support company were overrun by the opposing forces (OPFOR) and were not allowed by the observer/controllers (OCs) to intervene in the ensuing water crisis. By approximately 1030 that morning, the light infantry unit depleted its supply of drinking water. These soldiers became progressively dehydrated and were not able to shelter themselves from the strong solar conditions. By about 1330, numerous soldiers from this unit were affected by varying degrees of incapacitating dehydration and heat exhaustion which required intervention with urgent helicopter evacuation. This resulted in a transient heat stress mass casualty situation at the WACH ER. This episode provided an important learning point, discussed in the brigade's subsequent after action review (AAR), with regard to the extreme importance of preserving primary and alternate water resupply lines to front line units that are not expected to have access to natural water sources during a particular mission.

Work-rest tables were not explicitly utilized as a means of modulating heat stress exposure. Even the Medical Company, which should have had the most awareness of the availability of work-rest and water requirement tables, did not use them. However, continuous command emphasis on hydration and use of man-made and natural shade as well as avoiding heavy continuous work during the hottest parts of the day kept the overall heat stress casualty rate well below the 5% rate that the work-rest tables are designed for. This suggests that unit discipline and attention to basic heat stress prevention rules-of-thumb by NCOs and officers in the field can be as effective as sophisticated quantitative decision aids. The brigade surgeon was also instrumental in keeping the brigade commander and his staff continuously focused on the heat stress threat.

MEDICAL

Medical operations for the Medical Company were of two types: real and simulated. The total number of soldiers evaluated at the Medical Company treatment tent between 13-19 August

(17 days inclusive) was 520 with a per day mean of 31 ± 16 (range: 14 - 58). Of the 520 total patients, 90 had heat stress illnesses for an average of 5 ± 3 heat casualties per day (range: 0 - 13). Heat stress casualties comprised 20 ± 3.3% of the total number of daily patients (range: 0-48%).

Among those with heat illness, numerous cases presented with painful leg, thigh, and/or abdominal heat cramps. Not infrequently, individuals with heat exhaustion and heat cramps had some degree of hyperventilation causing circumoral and peripheral paresthesias as well as carpo-pedal spasms. Many troops brought to the treatment tent for evaluation, however, had nonspecific symptoms, appeared worn out, had normal core temperatures, and appeared clinically dehydrated with somewhat sunken eyeballs, poor skin turgor, and dry oral and ocular mucous membranes. Many of these individuals had a positive tilt-test (standing heart rate 20 or more beats per minute greater than sitting or supine). These soldiers received treatment for dehydration and/or mild-moderate heat exhaustion. Typical treatment consisted of several liters of isotonic IV fluids with rest and observation for several to twenty four hours in the adjacent medical holding tent (GP medium) and subsequent return to duty. There were several soldiers who had multiple or recurrent episodes of heat exhaustion. These soldiers were evacuated to the division medical hold detachment for further recuperation and disposition.

Several cases of heat illness were associated with altered mental status and disorientation. One of these soldiers was found unconscious in a defensive position along his unit's perimeter. This soldier was stuporous when he arrived at the treatment tent and had a moderately elevated core temperature. He was cooled, stabilized, and evacuated by UH-60 to the WACH ER. He made an uneventful recovery and was discharged from WACH with a diagnosis of heat stroke. Altered mental status in the context of operations in environments creating high risk for heat illness will usually be due to heat stroke, severe heat exhaustion or dehydration, or less commonly hyponatremia. It is critical, however, that the medical officer evaluating such a patient conduct this type of initial emergency assessment in an expeditious, but thorough, manner, keeping the full range of the differential diagnoses of altered mental status, stupor, and coma in mind and not jump to premature conclusions (Ropper and Martin, 1991).

Rectal temperature and a set of supine and sitting or standing vital signs (VSs) were routinely obtained for suspected heat illness cases in the medical company triage and treatment tent. If the patient had lightheadedness or excessive weakness, only supine VSs were obtained. The highest core temperature recorded in patients evaluated in the treatment tent was 103.5 °F. Soldiers with elevated core temperature had their shirts, boots, and socks removed. Their skin was cooled with evaporation of water from a spray bottle if the skin was dry or, in some cases, the application of ice water soaked towels. Because digital rectal thermometers were not available, serial temperatures were difficult to obtain.

The use of rest and isotonic IV fluids for heat exhaustion was usually effective treatment. Heat exhaustion cases typically received 2-6 liters of Ringer's Lactate (RL) intravenously (IV). Several soldiers with heat exhaustion who received 6-8 liters of IV RL subsequently developed mild generalized edema noticeable, because of the boots and uniform, in the hands and face. None of these individuals developed dyspnea and their lungs remained clear to auscultation. The edema usually resolved within 24 hours after discontinuation of the IV. Intravenous fluid infusions were discontinued when the patient began to evacuate significant amounts of clear urine and resting heart rate and blood pressure tilt-test reverted to normal. Heat stress casualties with mental status changes that did not respond rapidly to cooling and fluid infusions were evacuated by Army air ambulance (UH-60) to the WACH ER. The use of medical support helicopters was the preferred method of evacuating heat casualties because of concern among the medical personnel about the lengthy evacuation time and possible heat stress associated with travel in field ambulances (occasionally with nonfunctioning air-conditioning units). The spontaneous bursting of mercury containing clinical thermometers due to the high ambient temperatures served as a clear example that heat related equipment problems may impact on patient care and should be considered prior to deployment to a very hot environment. The problem with the thermometers specifically illustrated the need for heat tolerant analog or digital clinical thermometers.

The medical company patient login and disposition notebooks were meticulously maintained on a twenty four hour basis by medical company medics manning the patient administrative desk inside the entrance of the treatment tent. In these notebooks were recorded

the date and time that a soldier was admitted to the treatment tent for evaluation, the discharge diagnosis, date and time of release, and whether the soldier was returned to duty or evacuated to division medical hold or WACH. Brigade personnel evacuated directly from the field to WACH were also tracked by the medical company staff. These medical administrative records were summarized daily to provide the brigade surgeon with patient care statistics to use in the evening briefing of the brigade commander and staff on the state of health of the brigade. Data presented in Appendix C, obtained from these records, reveal that for the first seventeen days of the training cycle for which brigade medical data was available, 90 individuals, or 18% of the patients, evaluated by medical company medical personnel or at the WACH ER had heat stress related illnesses. The estimated activity level in Appendix C is a subjective estimate (by the author) of average activity level for the soldiers in the brigade based on a description of the overall brigade activities. Level 1 represents baseline activity that occurred on days for rest and recovery or administrative activities. Level 5 represents intense overall activity such as field maneuver, live fire, or force on force simulated combat. Multiple regression and correlation analysis (Spearman) did not (i.e., $P>0.05$) reveal significant associations between the daily number of heat stress casualties and noontime WBGT, WBGT heat stress category, estimates of overall daily brigade activity levels, or simple cross products (interactions) of these variables. Additionally, there were no significant correlations between daily heat stress casualties and previous day (i.e., one day lag) WBGT , WBGT category, or activity level.

Although there was not a statistically significant correlation between the number of heat stress casualties and noontime WBGT or activity level for the entire training rotation, perusal of figure 2 suggests that negative correlations in some segments of the data balanced positive correlations in other data segments. There are plausible explanations for the principal features of the heat stress incident rates in relationship to activity level. The initial relatively high rate of heat stress casualties could be due to the presence of some unacclimatized troops and moderately elevated WBGT rather than activity level. The peaks in heat stress casualties on 11 and 16 August could be attributably largely to the increased activity levels associated with rapid pace simulated combat scenarios. Likewise, the drop in heat stress casualties on 13 August was associated with a day interlude between the rapid tempo training scenarios. If the data utilized to

obtain the correlations had not included the initial acclimatization period, the positive association between activity level and daily incidence of heat stress casualties might have reached statistical significance. Based on a visual assessment of figure 2, one is led to concur with the correlation statistics that there was little if no association between noontime WBGTs and incidence of heat stress casualties.

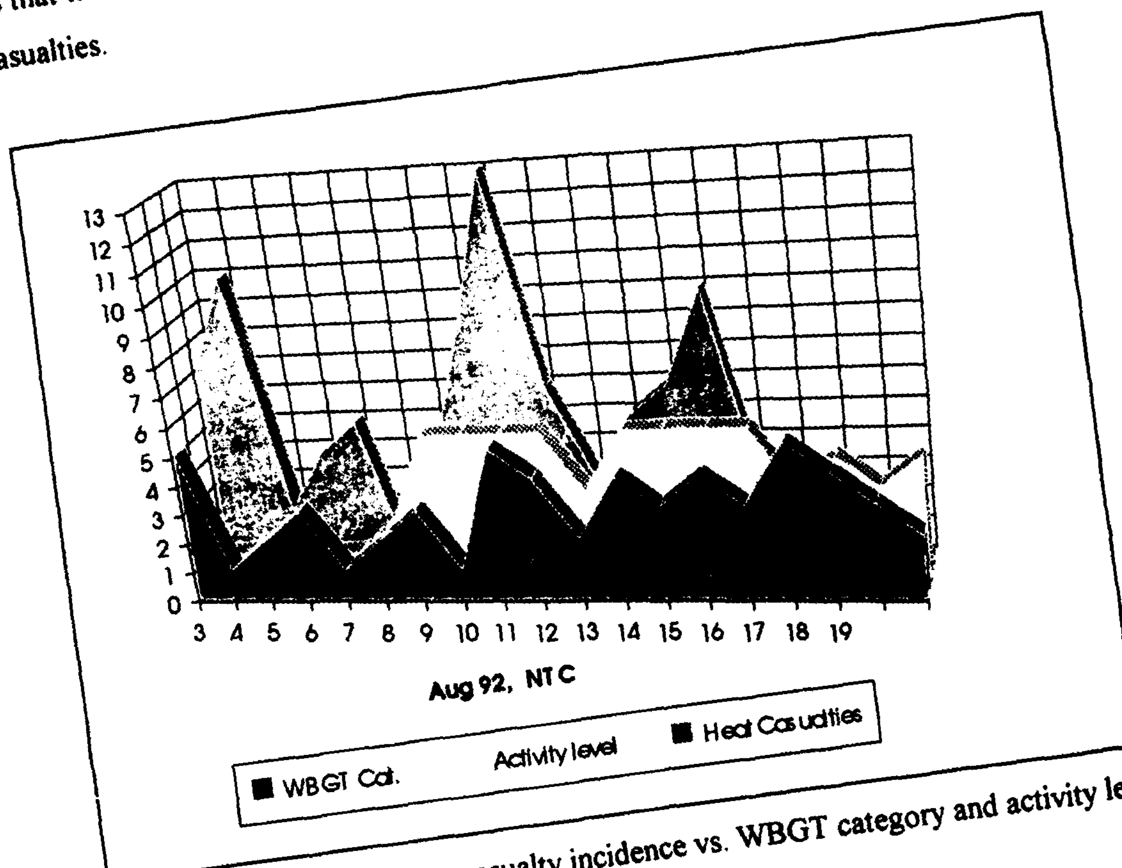


Figure 2: Graph of heat stress casualty incidence vs. WBGT category and activity levels.

The day-to-day variance in the number of daily heat stress casualties could have been due to significant individual and small unit deviations from the average overall estimated activity level as well as local variations in WBGT from the reference (Preventive Medicine) WBGT.

The table 2 below provides a rough comparison of the heat illness incidence rate for the 3rd Brigade versus rates since World War II (Kersten, et al., 1986; Minard, 1961; Hanson, 1991). The rate for World War II, Middle East is considered unrealistically low. The rate for Vietnam may be reasonably accurate, however, it does not include heat related dermatologic complications

which were a very frequent cause of disability and lost duty days for may combat units in the saturated Mekong Delta region. Rate comparisons are also problematic because the denominators are not normalized for comparable risk exposure. The denominator for calculating heat illness incidences ideally should account for person days of heat stress exposure. Such a measure of risk theoretically could be formulated as an integral, over time and number of personnel, of WBGT, metabolic rate, type of uniform, MOPP level, and other risk factors. Under most circumstances, however, with current sensor technology, such a complex measure of risk for heat illness would be impractical to implement. In the future, advances in sensors and telemetry may enable this expanded concept of risk measurement and tracking, at least partly, feasible.

	Year(s) (Summer only)	# heat illnesses/10,000/week	Primary Activity	Notes
Army (MiddleEast, WWII)	1943	11	Admin., CSS	This rate is considered low and unreliable.
Marine recruits (Parris Island)	1952-3 1954 1955 1956	39.5 12.4 4.7	Recruit training including class-room time.	Use of WBGT & work/rest cycles dramatically lowers rate.
Marine reserves	1959	32.7	Amphibious	FTX, 29 Palms, CA
Army & Marines	1960s	378	Combat ops.	Vietnam, estimate.
Marine reserves	1980	308	Simulated combat.	FTX, 29 Palms, CA
Army Reserve mech inf	1986-89	159	Simulated combat.	Midwest training area
Marines (Desert Shield)	1990	28	Passive defense & desert ops. training.	Saudi Arabia, early entry defensive and training ops.
Army mech inf.	1992	84	Simulated 24hr/day combat.	NTC, Ft. Irwin. Hot-dry desert. Experienced, acclimated, active duty unit.

Table 2. Heat stress casualty rates

Characteristics of soldiers with heat stress injuries evacuated directly from the field to the WACH ER are included in the table below:

N=16	Mean:	Std Dev:
Age:	23.2	4.4
Rank:	3.4	1.4
Initial temp in field (°F):	101.0	1.6
Initial temp in ER (°F):	99.2	0.8
Field-ER temp change (°F):	1.5 (P<0.05)	1.8
Field-ER HR change (beats per min):	-2.6 (NS)	16.3
IV fluids in field (lts):	3.4	1.6
IV fluids in ER (lts):	2.4	0.8
Total lts IV fluids required (lts):	92.8	
Mean ER time (hrs:mins):	2:35	0:50
Days of quarters:	1.3	0.5

Table 3: Heat stress casualties evacuated directly from the field to WACH ER

These data indicate that brigade heat stress casualties evacuated directly from the field to the WACH ER were young soldiers in the lower enlisted ranks. Their initial core temperatures obtained in the field by medics were moderately elevated. The interval of time between the soldier becoming a heat stress casualty and measurement of the initial core temperatures in the field, however, was not recorded and therefore could not be ascertained. Core temperatures fell, on average, 1.5 °F during transport to the WACH ER. These patients were each treated, on average, with 5.8 liters of IV fluids. It is apparent, even with this rather limited data, that a substantial amount of evacuation, personnel, and supply resources were required to evacuate and treat these patients.

Numerous methods of cooling heat stroke patients have been investigated. Disrobing a patient and spraying with a fine water mist with simultaneous use of fans to enhance airflow and evaporative cooling rate has been shown to reduce core temperature at rates of 0.03-0.06 °C/min (0.054-0.108 °F/min or 0.54-1.08 °F/10 min) (Scott, 1989). Poulton and Walker (1987) reported

an average cooling rate of 0.104 °C/min (1.87 °F/10 min) for heat stroke patients cooled by helicopter rotor down wash (48-55 km/hr). The most effective cooling method, however, is ice-bath immersion with vigorous massaging to promote skin and muscle blood flow. Ice water immersion, as utilized by heat casualty response teams at the Parris Island Marine recruit training base, has resulted in cooling rates of 0.15 °C/min (2.7 °F/10 min) (Costrini, 1989).

ENVIRONMENTAL TEMPERATURE PROFILES

Figure 3 is a graph of the noontime WBGT and WBGT component temperatures recorded just outside the Preventive Medicine office, adjacent to WACH, on Fort Irwin's main post.

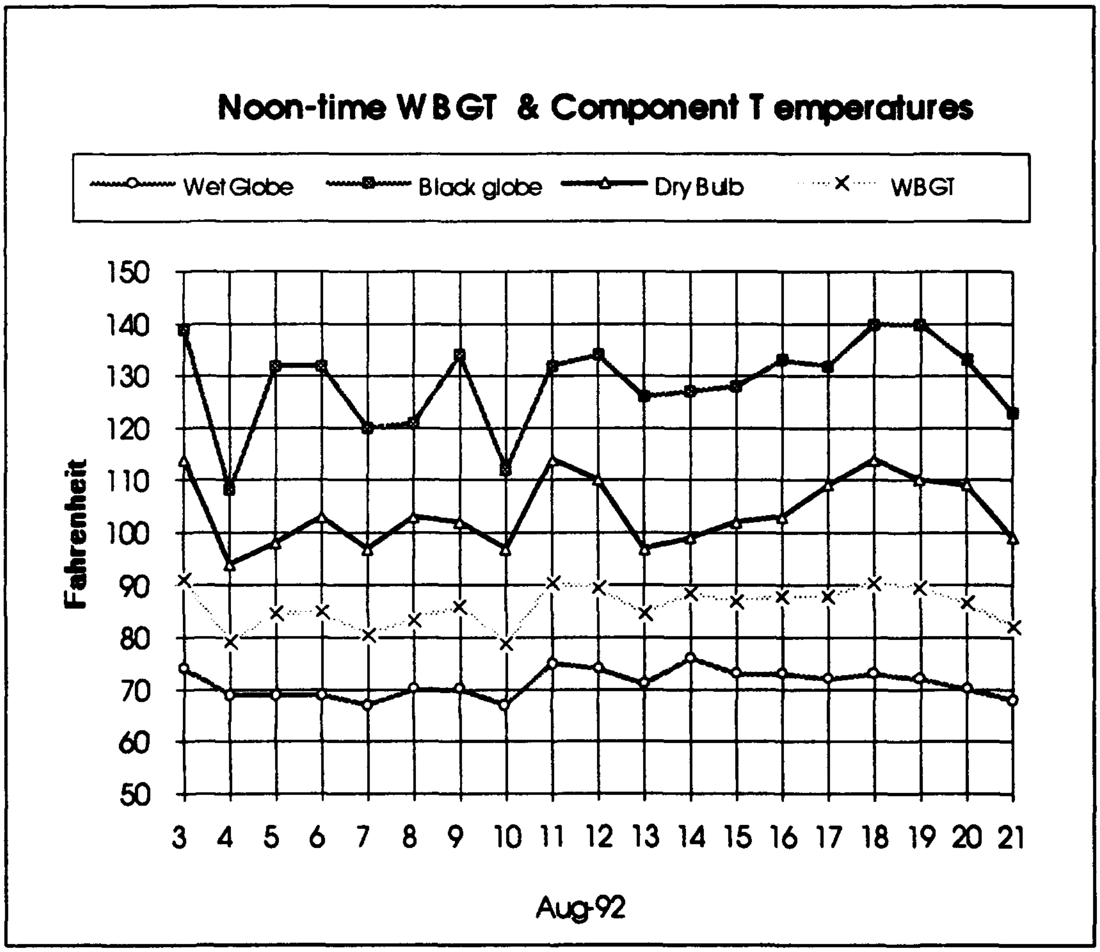


Figure 3: WBGT profile at the Ft. Irwin PM facility

The temperatures in figure 3 were obtained from a tripod mounted Stortz Wetbulb/Globe Temperature Kit (NSN 6665-00-159-2218, PSG Industries). This Stortz WBGT kit was maintained in the direct sun approximately four feet above the ground a short distance outside the Fort Irwin Preventive Medicine building across the street from the WACH.

The elevated black globe temperatures confirmed the personal sensation that the radiant heat load was significant. Relatively mild wet bulb temperatures were due to the low daytime humidity (~20%) and high evaporative capacity of the warm ambient desert air. It is interesting to note the differences in dynamic range for the WBGT and constituent temperatures. The wet bulb temperature varied within a 10 °F range, shaded dry bulb temperature varied within approximately a 20 °F range, and black globe temperature varied within about a 30 °F range. Since WBGT =0.7* wet bulb + 0.2*black globe + 0.1*dry bulb, the variation in WBGT most closely tracked the variation in wet bulb. The WBGT's dynamic range, therefore, was also about 10 °F.

Detailed daytime environmental temperature profiles recorded by the Metrosonics data logger within the NTC training area from 14-19 August are included in Appendix C. The WBGT and component temperature graphs in Appendix C demonstrate a number of features. Sunrise and sunset times were closely correlated with the black globe and dry bulb temperature crossover points. Morning temperatures rose rapidly over approximately two hours after sunrise. Solar radiation, as indicated by black globe temperature, reached maximum levels and became relatively stable between approximately 1000 to 1700 hours. Dry bulb temperatures, after the initial two hour rapid rise associated with sunrise, continued to rise at a more gradual rate throughout the day until about 1700 hours. After about 1700 hours, the dry bulb and black globe temperatures began a gradual decline that continued through sunset and into the evening. After sunset the black globe was slightly less than the dry bulb temperature due to greater radiant heat loss from the black globe to the empyrean. Artifacts due to desiccation of the wet bulb's wick are readily identified as sharply defined transients in the wet bulb temperature profiles that rapidly corrected when the wick was rewetted.

SIMULATED CASUALTIES

Simulated casualties evacuated to the Medical Company from all the brigade's constituent units were numerous. Most of the simulated casualties were generated by MILES during the phases of simulated combat. Additional simulated casualties were designated by observer-controllers (OCs) as unit penalties for divers infractions of doctrine or safety. Simulated casualties required evacuation to the Medical Company for evaluation and simulated treatment. They then rested in the company area until retrieved by their units. These casualties provided the medical company and supporting medical evacuation UH-60 detachment with sustained mass casualty practice. There were many days when medics were carrying simulated liter patients back and forth between ambulance loading areas and treatment tents during the hottest parts of the day. Several of the Medical Company medics succumbed to heat exhaustion. Additional personnel to augment the medical company litter teams were requested and received from other companies of the FSB. This situation illustrated that in hot weather medical commanders and physicians must protect medics from heat injury by requesting additional personnel and other support from adjacent units, providing sufficient time to drink water, and using work rest cycles.

DISCUSSION

Heat stress illnesses were expeditiously evaluated and triaged. Treatment was effective and serious complications avoided. Most soldiers were able to return to their units within 1-2 days. Excessive infusion of IV fluids resulted in edema in several soldiers. A systematic approach to the use of IV fluids and electrolytes in the treatment of heat exhaustion is summarized in the following quotation (IV potassium should usually only be utilized if clinical lab equipment is available to confirm beforehand that baseline serum potassium, BUN, and creatinine levels are not elevated):

> "Patients with evidence of clinically significant plasma volume depletion (tachycardia at rest or orthostatic signs) should initially receive normal saline in

200-250 cc boluses in an amount sufficient to restore normal circulatory function. No more than 2 liters of NS should be administered without laboratory surveillance. Subsequent parenteral fluid replacement should be D5/0.5 NS or D5/0.2 NS. Individuals with significant salt depletion have coincident potassium depletion, often amounting to 300-400 meq of KCl. To begin the restoration of the potassium deficit, inclusion of potassium in parenteral fluids after volume resuscitation is appropriate if there is no evidence of renal insufficiency or rhabdomyolysis. Oral fluids should not be given until all risk of vomiting has abated. Significant hypernatremia should be avoided to avoid cerebral edema" (Burr, 1991).

Consistent with these guidelines, heat exhaustion patients evaluated in the Medical Company treatment tent who did not exhibit significant improvement in symptoms after having received two liters of normal saline or Ringer's lactate did not seem to benefit by further fluid infusion. The Medical Company did not have laboratory equipment to permit determination of serum electrolytes. Several of the soldiers evacuated to the WACH ER had mildly elevated serum sodium levels and it is possible that of the soldiers who exhibited poor response to IV fluid infusion in the Medical Company treatment tent some may have had electrolyte abnormalities as part of their problem

In the desert, hypernatremia is most frequently secondary to inadequate replacement of sweat related free water loss. Adequate water supplies and command emphasis on rehydration will usually prevent hypernatremic dehydration. The 3rd Brigade leaders were quite diligent in this regard. Hyponatremia, in the field setting, is usually due to inadequate dietary intake of salt (NaCl). This is most commonly due to insufficient intake of rations. For soldiers in the field during hot weather, the guidelines for salt and diet are as follows:

> "Adequate food intake helps maintain adequate sodium intake. Under most circumstances, military rations contain adequate amounts of salt to replace the sodium that is lost in sweat. However, during the initial 8

days of heat exposure, especially if the soldiers are not heat acclimatized, they should lightly season their meals with table salt. When food intake decreases drastically, (e.g. only one meal per day), additional salt in the form of a very dilute salt solution may be necessary. This solution is made by adding 1/4 teaspoon table salt (1/4 MRE salt packet) to each quart of drinking water. Never use salt tablets without the recommendation of and supervision by a medical officer. Salt tablets consumed in excess of sodium needs actually contribute to dehydration by increasing water requirements.

The ideal diet for hot weather operations is one that focuses on complex carbohydrates, with adequate protein and moderate fat. Carbohydrates serve as a fast fuel source, replace muscle carbohydrate (glycogen) stores, and spare protein reserves. In addition, the body stores glycogen with water so burning glycogen during physical activity produces metabolic water" (Thomas, et al., 1993).

Medical units see the effects of heat stress as heat casualties. The adverse effects of heat stress, however, extend beyond the obvious medical consequences. Heat stress may adversely affect mood, morale, judgment, and performance. Prolonged exposure to hot environments increases the time for individuals to complete complex tasks. In recognition of this phenomenon the National Institute of Occupational Health and Safety (NIOSH) has published maximum recommended exposure times for unimpaired mental performance as a function of WBGT. Linear models exist that can provide quantitative estimates of performance decrements for various types of tasks as functions of duration at specific WBGT levels (Ramsey & Morrissey, 1978). It has been determined, however, that many of these mental and cognitive decrements can be substantially mitigated by training individuals to high levels of task proficiency prior to heat exposure (Handcock, 1982). Impairment of performance and cognition has also been correlated with amount or percent dehydration (Gopinathan, et al., 1988).

Hot weather, via many mechanisms, may impair vigilance during surveillance and sentry duty. Soldiers suppress activity to decrease metabolic heat gain. This predisposes to nodding off

as does the frequently monotonous terrain and lack of movement of others who are themselves shielded from the sun. Visual perception may be impaired by mirages and other hot weather related illusions caused by convective air currents over hot surfaces. Sweat flowing into a soldier's eyes may physically cause visual lapses that could be important in certain assignments (Kobrick and Johnson, 1992).

Hot environments can have other adverse effects on human factors. For example, heat related peripheral edema that frequently occurs during acclimatization may mechanically impair normal joint function making tasks dependent on rapid or fine movements more difficult. Human-machine interfaces may become problematic. Hand sweat may make knobs and switches in vehicles, aircraft, or on communications equipment difficult to manipulated. Metallic objects may become uncomfortably warm. Gloves may be necessary to protect the skin from hot surfaces of vehicles or weapons that are exposed to direct solar radiation. Heat stress in enclosed vehicles such as tanks and helicopters may become intolerable and require the use of microclimate cooling (Kobrick and Johnson, 1992).

Among the soldiers of the 3rd Brigade no serious medical sequelae of heat illness occurred. It is well established however, that the most serious form of heat illness, heat stroke, is often accompanied by cardiovascular collapse, shock, lactic acidosis, electrolyte abnormalities and diffuse damage to a wide variety of organ systems. Such organ system damage may include hepatocellular necrosis with markedly elevated serum enzymes, renal insufficiency, myocardial depression with patchy or diffuse myocardial cellular disruption, acute respiratory distress syndrome, as well as rhabdomyolysis with myoglobinuria, life threatening hyperkalemia, and hyperuricemia (Glowes Jr. and O'Donnell Jr, 1974).

Rhabdomyolysis, if it occurs, must be detected early so that appropriate measures can be taken to preserve renal function and obtain surgical consultation for a possible compartment syndrome. Seizures associated with heat stroke or hyponatremia may cause rhabdomyolysis. Rhabdomyolysis due to lower extremity compartment syndrome requires immediate surgical referral for possible faciotomy. Compartment syndrome with muscle damage and compression

neuropathy may result in disability (e.g. inability to dorsiflex the foot) due to scarring of damaged muscle tissue and peroneal nerve palsy. It has been estimated that, for myoglobin to appear in the urine, at least 200 grams of muscle tissue must be damaged - assuming a renal threshold of 0.3 mg/ml (Rowland and Penn, 1972). Demos, et al. (1974) demonstrated that subclinical low level (below the renal threshold) myoglobinemia occurred at least once in 75% of the marines they studied at the Marine Recruit Training Base in Parris Island, SC. Those who had no myogloinemia as well as those with low levels of asymptomatic myoglobinemia had the same "normal" increases in CPK (mean 1,413, range 159 - 9,903 mU/ml) attributed to the rigorous training. Those with clinically apparent rhabdomyolysis had 10-100 times greater values for serum myoglobin than those who were asymptomatic. Clinically apparent rhabdomyolysis was also associated with more severely elevated CPK enzyme levels (mean 76,803, range 26,708 -109,609). It has been demonstrated that T2-weighted magnetic resonance imaging (MRI) can be used to confirm the location and extent of muscle groups affected by rhabdomyolysis (Shintani and Shigai, 1993). The damaged muscle, in these MRIs, will initially present as areas of noticeably higher image intensity. Usually the affected muscles in exertional rhabdomyolysis are in the lower extremities, however, upper extremity and shoulder girdle rhabdomyolysis can definitely occur (Hurley, 1989). For example, rhabdomyolysis of the pectoralis and triceps has been reported in soldiers who have done an excessive number of pushups or who were forced to maintain themselves in the up pushup position for an excessive period of time.

Cerebral and cerebellar dysfunction are hallmarks of heat stroke and may take several weeks or months to fully resolve (Mehta and Baker, 1970). Rarely, such impairment may persist. In lethal cases of heat stroke, autopsies have demonstrated cerebral edema, diffuse petechia, and neurolysis, particularly of the cerebellar Purkinje cells but also affecting the dentate and other basal nuclei, and the pons. An unusual but debilitating neurologic complication of heat stroke is thrombosis of the anterior spinal artery with lower extremity paralysis (Amundson, 1989). A case report also exists of chromatolysis and neurophagia of anterior and anterolateral horn cells of the lumbar cord (Delgado, et al., 1985).

Heat stroke may be accompanied by endothelial cell damage as well as a consumptive coagulopathy (DIC) with prolonged PT and PTT, depression of platelet count, and decreased fibrinogen levels (Anderson, Reed, and Knochel, 1983). According to El-Kassimi, et al. (1986), clinically significant DIC often occurs in conjunction with adult respiratory distress syndrome (ARDS). In their series of 52 heat stroke victims, 23% developed ARDS. All of these ARDS patients also developed DIC, whereas, only 2.5% of those with heat stroke but without ARDS developed DIC.

The clinician must be cautious in the primary evaluation of heat illness patients because hepatic enzyme levels and coagulation tests may take 24-72 hours to become significantly abnormal. Therefore, initially normal or only slightly abnormal lab tests should not be relied upon to distinguish heat exhaustion from heat stroke. When doubt exists, the patient must be retained or evacuated for follow-up testing and observation for at least 48-72 hours.

Not uncommonly soldiers evaluated for heat stress by the medical company presented with varying degrees of hyperventilation. All of these patients promptly responded to reassurance, rest, and hydration. Patients with heat stress and hyperventilation who do not respond to such treatment obviously require additional evaluation. One possibility is heat stroke related metabolic acidosis with compensatory hyperventilation. In severe heat illness, the possibility of acidosis secondary to renal failure must be considered so that appropriate lab testing and treatment can be provided (e.g., serum potassium levels can rapidly rise to life threatening levels). In a series of cases of heat stress related renal failure, reported by Vertel and Knochel (1967), sixty percent of the cases had recent evaluations for heat exhaustion, fifty percent presented with hypotension. and forty percent of the cases were associated with rhabdomyolysis. Recurrent heat illness, hypotension, and clinical indications of rhabdomyolysis should therefore indicate the necessity of evaluating renal function. The cases of heat induced renal failure described by Vertel and Knochel required an average of 2-3 weeks of hemodialysis to permit survival while renal function recovered. The overall mortality, however, was twenty percent. Vertel and Knochel pointed out that other studies demonstrated that healthy kidneys are usually capable of clearing relatively

large myoglobin loads without adverse sequelae. They postulated, therefore, that myoglobin induced renal failure is greatly potentiated by dehydration, shock, and hypoxia.

Symptomatic heat stress related hyponatremia, although relatively uncommon, may occur as a complication of prolonged exertion in hot environments. Noakes, et al. (1990) reported that 9% of those that collapsed during ultramarathons had serum sodium levels below 130. Moore et al. (1992), however, did not find significant changes in serum sodium levels in a study of US Army Ranger trainees and no significantly decreased sodium levels were detected in the heat stress casualties in this report who had lab work. The occurrence of heat stress related hyponatremia in soldier populations is sporadic. Although severe hyponatremia occurs unpredictability it may be lethal if not recognized and treated appropriately therefore, this diagnosis must be considered when evaluating a heat stress casualty with seizures, altered mental status, or coma. Hyponatremia may occur because of inadequate dietary sodium intake and large sodium losses via prolonged sweating replaced only by clear fluids. In such situations the individual is likely to have clinical findings consistent with dehydration. On the other hand, stress, nausea, vomiting, and certain medications (including tricyclic antidepressants, carbamazapine, hypoglycemic agents, acetaminophen, and NSAIDs) may cause some degree of SIADH resulting in expansion of total body water with a normal quantity of total body sodium. In such cases the individual will not have clinical manifestations of dehydration. There are many other important causes of SIADH, not discussed here, that are not related to environmental or physical stress.

Hyponatremia commonly results in mental status and neurologic symptoms and may be lethal. Below a sodium of 130 meq/L an individual may become confused, stupor may develop at levels below 125, and coma with seizures are common at or below 120 (Arieff, 1987; Moses and Miller, 1974). Although central pontine myelinosis may occur with rapid over correction of the serum sodium, severely symptomatic patients should have their sodium levels corrected initially at a rate of 1-2 meq/hour with small boluses of 5% hypertonic saline to elevate the serum sodium level to about 125 meq/L in order to bring the patient out of the coma or stupor and elevate the low seizure threshold. A diuretic may be used if there is evidence of fluid overload. Subsequently the sodium level is corrected more gradually with isotonic saline, oral sodium-containing fluids (if

the patient is alert), or water restriction (if there is evidence of water excess or SIADH) to bring the serum sodium back into the normal range (Levinsky, 1991).

CONCLUSIONS

The NTC during August can be considered an excellent field location for USARIEM physicians to evaluate and treat many cases of heat related illnesses. A long term data collection collaborative effort could be established with rotational units as well as WACH and the Preventive Medicine Activity at Fort Irwin. Since the NTC training areas are heavily instrumented with various sensors, and operations are videotaped by video cameras situated on various hilltops, it might be possible to exploit this capability to better evaluate, in an operational setting, the links between environmental conditions, soldier activities, uniform, soldier loads, and heat stress casualties. An effort such as this would undoubtedly have to be coordinated through the NTC headquarters.

A review of some relevant observations:

- The rate of heat stress illness for this particular brigade was relatively low despite high WBGTs and a rapid paced training scenario. There were several cases of heat stroke but these individuals recovered without adverse sequelae.

- The incidence of heat illness was about one half the rate of an Army Reserve mechanized infantry brigade described by Korenyi-Both and Dellva (1991).

- Heat illness occurred primarily among the lower ranking enlisted soldiers less than 30 years of age.

- Heat exhaustion cases often had only mild-moderately elevated core (rectal) temperatures when presenting to the treatment tent. Those who were transferred to the ER typically had somewhat higher core temperatures and experienced decreases of 1.5°F in core temperature during transportation.

- In this particular case, there was no statistically significant correlation between noontime WBGTs or estimated activity levels and incidence of heat illnesses. In part this was due to avoidance of activities, as much as possible during the midday.

- Low humidity suppressed the effects of high black globe temperatures on the WBGT. The WBGT heat stress levels were symmetrically distributed.

- Convective cooling methods were not often utilized. Low wet bulb temperatures indicated that this would have been an effective method of cooling fluids.

- Carrying litters is a high intensity activity. These soldiers need to be relieved often to allow them to rest and prevent excess heat storage. Personnel to form extra litter teams should be requested from local combat service support units through the brigade and division support command (DISCOM) chains of command.

- Poor planning and/or implementation of field sanitation (latrine) facilities as well as not providing for privacy expedients for mixed gender units leads to suppression of water consumption in order to minimize voiding in public.

- Uncooled IV fluids and drinking water during the day were typically above 100°F, i.e. above body temperature. Heat stress casualties should not be infused with IV fluids that are at higher than normal body temperature. The desire for iced water is an adaptive response of the soldier to the extra heat load imposed by drinking water at elevated temperature.

- Standard mercury clinical thermometers rupture if the ambient temperatures become high enough (about 110°F).

- In the desert, where there are few if any readily accessible surface water sources, units need to be extremely careful to ensure that they will not run out of water. Also, water resupply needs careful planning. Contingency water resupply plans must always be prepared and be ready for immediate implementation for units that may become stranded or surrounded. Incapacitating dehydration and heat illness can develop within only a few hours in soldiers who deplete their water supplies, cannot find shade, and must continue exerting themselves to evade or fight off a pursuing enemy.

REFERENCES

Adolph, E. F., et al. Physiology of Man in the Desert. NY: John Wiley & Sons, 1947.

Allan, J.R. and Crossley, R.J. Effect of controlled elevation of body temperature on human tolerance to +Gz acceleration. Journal of Applied Physiology 33: 418-420, 1972.

Amundsun, D.E. The spectrum of heat related injury with compartment syndrome. Military Medicine 154: 450-452, 1989.

Anderson, R.J., Reed, G., and Knochel, J. Heatstroke. 1983 Year Book of Internal Medicine, Year Book Medical Publishers, Inc., 1983.

Bolger, D. P. Dragons at war: land battle in the desert. Ballantine Books, NY, 1986.

Burr, R.E. Heat illness: a handbook for medical officers. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Note TN91-3, 1991.

Clegg, R.H. Environmental influences on desert operations. Infantry 28-34, May-June 1992.

Clowes, G.H.A., and O'Donnell, T.F. Jr. Current concepts: heat stroke. New England Journal of Medicine 291(11): 564-566, 1974.

Costrini, A. Emergency treatment of exertional heatstroke and comparison of whole body cooling technique. Medicine and Science in Sports and Exercise 22(1): 15-18, 1990.

Delgado, G., Tunon, T., Gallego, J., and Villanueva, J.A. Spinal cord lesions in heat stroke. Journal of Neurology and Neurosurgical Psychiatry 43:1065-1067, 1985.

Demos, M.A., Gitin, E.L., and Kagen, L.J. Exercise myoglobinemia and acute rhabdomyolysis. Archives of Internal Medicine 134: 669-673, 1974.

El-Kassimi, F.A., Al-Mashhadani, S., Abdullah, A.K., and Akhtar, J. Adult respiratory distress syndrome and disseminated intravascular coagulation complicating heat stroke. Chest 90 (4):571-574, 1986.

Froom, P., Shochat, I., Strichman, L., Cohen, A., and Epstein, Y. Heat stress on helicopter pilots during ground standby. Aviation Space and Environmental Medicine 62: 978-981, 1991.

Gopinathan, P.M and Sharma, V.M.. Role of dehydration in heat stress-induced variations in mental performance. Archives of Environmental Health 43: 15-17, 1988.

Halbertstadt, Hans. NTC: A primer of modern land combat. Presidio Press, Novato, CA, 1989.

Handcock, P.A. Task categorization and the limits of human performance in extreme heat. Aviation Space and Environmental Medicine 53: 778-784, 1982.

Hansen, K. Summary of disease surveillance information from Operation Desert Storm (unpublished). Honolulu HI: Naval Environmental Preventive Medicine Unit (NEPMU) Six, 1991.

Hurley, J.K. Severe rhabdomyolysis in well conditioned athletes. Military Medicine 154(5):244-245, 1989.

Kerstein, M.D., Wright, D., Connelly, J., and Hubbard, R. Heat illness in hot/humid environment. Military Medicine 151(6): 308-311, 1986.

Kobrick, J.L. and Johnson, R.F. Effects of hot and cold environments on military performance. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Report T7-92, 1992.

Korenyi-Both, A.L. and Dellva, W.L. Prevalence of injuries and illnesses of a reserve separate infantry brigade (separate) during annual training. Military Medicine 156, 1991.

Levinsky, N.G. Fluids and electrolytes. In: Harrison's Principles of Internal Medicine (12th Edition). J.D. Wilson, E. Braunwald, K.J. Isselbacher, R.G. Petersdorf, J.B. Martin, A.S. Fauci, and R.K. Root (Eds). McGraw-Hill Inc., Health Professions Division, New York City, 193-200, 1991.

Mehta, A.C. and Baker, R.N. Persistant neurological deficits in heat stroke. Neurology 20(4): 336-340, 1970.

Minard, D. Prevention of heat casualties in Marine Corps recruits. Military Medicine 126: 261-372, 1961.

Mitchell, G.W. Rapid onset of severe heat illness: a case report. Aviation Space and Environmental Medicine 62: 779-782, 1991.

Moore, R.J., Friedl, K.E., Kramer, T.R., Martinez-Lopez, L.E., Hoyt, R.W., Tulley, R.E., DeLaney, J.P., Askew, W.E., Vogel, J.A. Changes in soldier nutritional status and immune function during the ranger training course. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Report T7-92, 1992.

Moses, A. M., and Miller, M. Drug-induced dilutional hyponatremia. New England Journal of Medicine 291(23): 1234-1239.

Naylor, S.D. Desert veterans duke it out at the NTC. Army Times 52(16), 1991.

Poulton, T.J. and Walker, R.A. Helicopter cooling of heatstroke victims. Aviation Space and Environmental Medicine 58: 358-361, 1987.

Ramsey, J.D. and Morrissey, S.J.. Isodecrement curves for task performance in hot environments. Applied Egonomics 66-72, June 1978.

Ropper, A.H. and Martin, J.B. Coma and other disorders of consciousness. In: Harrison's Principles of Internal Medicine (12th Edition). J.D. Wilson, E. Braunwald, K.J. Isselbacher, R.G. Petersdorf, J.B. Martin, A.S. Fauci, and R.K. Root (Eds). McGraw-Hill Inc., Health Professions Division, New York City, 193-200, 1991.

Rowland, L.P. and Penn, A.S. Myoglobinemia. Medical Clinics of North America 56(6): 1233-1256, 1972.

Santee, W.R., Matthew, W.T., and Tharion, W.J. Simulated approach marches during thermal stress: a P2NBC2 study. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Report T12-92, 1992.

Scott, J. Heat related illnesses: when are they a true emergency? Postgraduate Medicine 85(8): 154-164, 1989.

Shintani, S. and Shiigai, T. Repeat MRI in acute rhabdomyolysis: correlation with clinicopathological findings. Journal of Computer Assisted Tomography 17(5): 786-791, 1993.

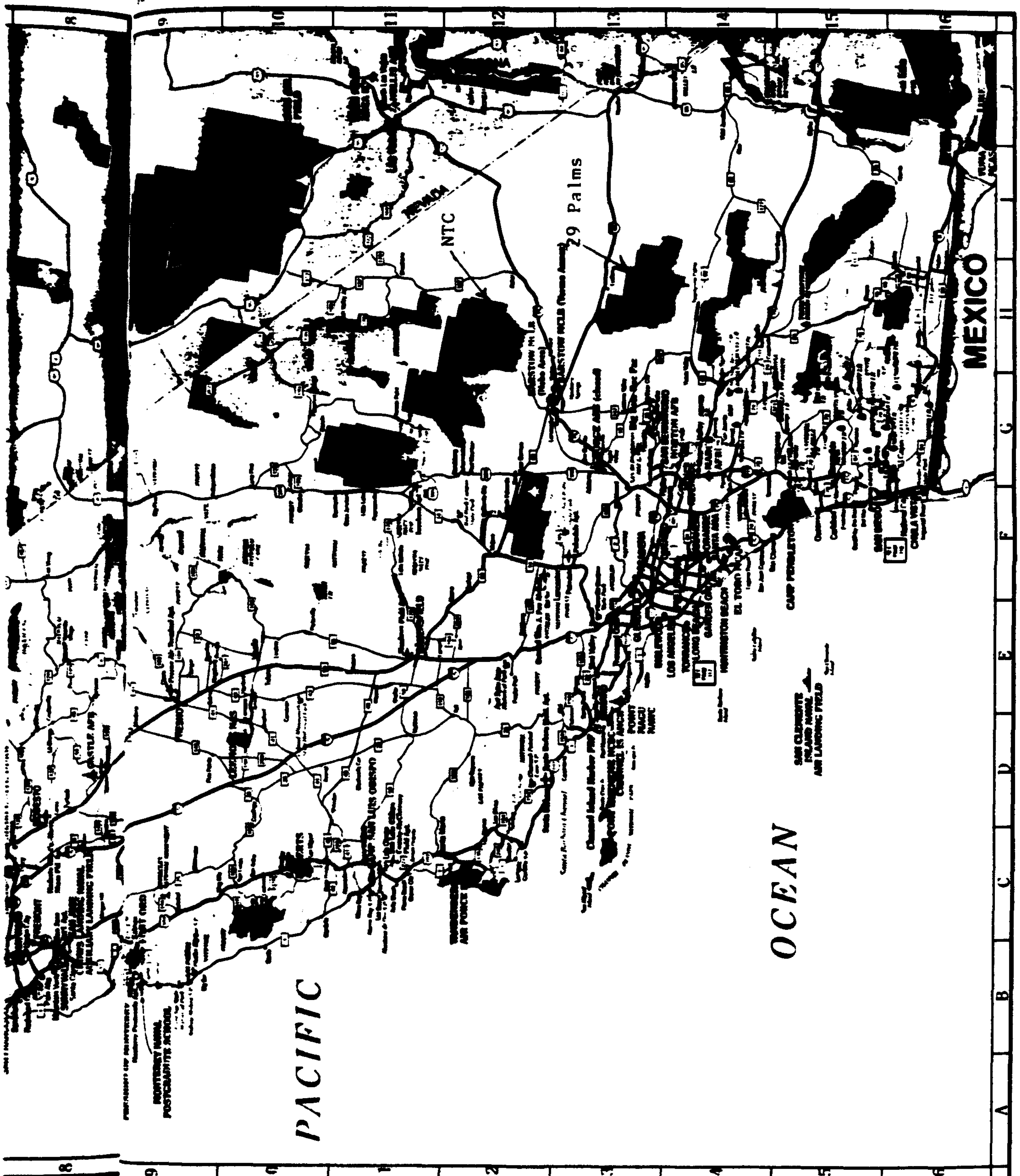
Thomas, C.D., Baker-Fulco, C.J., Jones, T.E., King, N., Jezior, D.A., Fairbrother, B.N., Speckman, K.L. and Askew, E.W. Nutritional guidance for military field operations in temperate and extreme environments. Natick, MA: U.S. Army Research Institute of Environmental Medicine, Technical Note TN93-8, 1993.

Vertel, R.M. and Knochel, J.P. Acute renal failure due to heat injury: an analysis of ten cases associated with a high incidence of myoglobinuria. American Journal of Medicine 43:435-450, 1967.

Zaloznick, A.J., Stinson, K.R., and Rennie, D.S. Impact of units on rotation at the National Training Center: the Fort Irwin MEDDAC experience. Military Medicine 158(10): 649-651, 1993.

APPENDIX A

A map of Fort Irwin and the NTC in Southern California



APPENDIX B

Metrosonics WBGT Datalogger Product Information

Provides Datalogging & Calculates Stay Time

WBGT

Dry bulb (DB), Wet bulb (WB) and Globe Temperatures (GT) are measured to a high degree of accuracy. Integrating this information, the hs-371 calculates and displays both indoor and outdoor WBGT, according to established formulas.

Stay Time

Work levels ranging from light to heavy are user-programmed into the hs-371. The type of work is then instantaneously factored with the WBGT, and the stay time (the amount of time an individual can safely stay in the area) is instantly calculated and displayed. The hs-371 computes stay time for US Navy PHEL and EPRI criteria.

Easy to Use

Operation is made simple with user-friendly menus and prompts. Various functions can be performed from the front panel keyboard (a security code is incorporated to prevent unauthorized access). In addition, the hs-371 xan be preset to automatically start a test at a future date and time, or it can be controlled remotely.

Complete Documentation

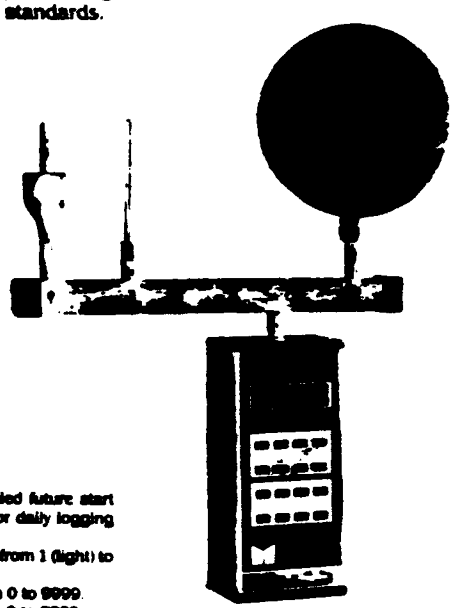
Fully formatted hard copy printouts may be obtained on standard RS-232 printers and used as incontestable documentation of the environment. Even the identification of the operators and their locations can be stored.

Data Storage

Unique microprocessor technology allows the hs-371 to store up to 2500 time history values of the measurements in its solid state memory for transfer to printer or computer. Test intervals can be selected from 1 minute resolution to 60 minutes.

Rugged Construction

Packaging is consistent with the hostile environments which the hs-371's are intended to measure. Their extruded aluminum cases and keypads are designed for rough handling and short term water immersion as per IEC standards.



Specifications

Temperature Sensors: pt 100 RTD's (Remoteable).

Measurement Range: 0 to +100° C (+32° to +212° F).

Measurement Accuracy: +0.5° C (0.9° F)

Globe Size:

- 371-2: 2 inch (50 mm) sphere internally referenced to a 6 inch (150 mm) Vernon Globe.
- 371-6: 6 inch (150 mm) globe.

DATA COLLECTION

Display: 2 x 16 character; alpha numeric.

Display Resolution: +0.1° C or F.

Update Rate: 1/Second.

Parameters: Dry bulb temp (DB), Wet bulb temp (WB), Globe temp (GT), Indoor and outdoor WBGT, current stay time, date and time, logged data

Test Intervals: Programmable from 1 to 60 minutes

Calendar Time: Day: Month: Year / Hour: Minute: Second (clock maintained when power is off).

Scheduled Run: Prescheduled future start time and duration for single or daily logging run.

Work Levels: Programmable from 1 (light) to 6 (heavy)

Area ID: Programmable from 0 to 9999.

User ID: Programmable from 0 to 9999.

OUTPUT MODES

Formatted: Preformatted ASCII data for terminals or printers. Time history and test specifics.

Binary: High rate proprietary formatted data for transmission to computer systems (same data as formatted mode).

DIGITAL COMMUNICATIONS

Type: 4 wire RS-232, X-On/X-Off or DTR.

Format: ASCII, 1 start, 8 data, 1 stop bit.

Baud Rate: 300, 600, 1200, 2400, 4800, 9600.

POWER

Batteries: 6 C-cells.

Battery Operation : 200 hours at 25° C.

Data Retention: 1 month.

External Power: 10 to 28 Vdc.

ENVIRONMENTAL

Operating Temperature: +0 to +74° C (+32 to +165° F).

Humidity: To 95% non-condensing. Short term water immersion in accord with IEC Standards 529-1978.

PHYSICAL

Instrument Size: 8 x 4 x 2 in. (20 x 10 x 7 cm)

Sensor Assembly Size:

- 371-2: 7 x 7 x 2 in. (18 x 18 x 5 cm)
- 371-6: 12 x 11 x 6 in. (30 x 28 x 15 cm)

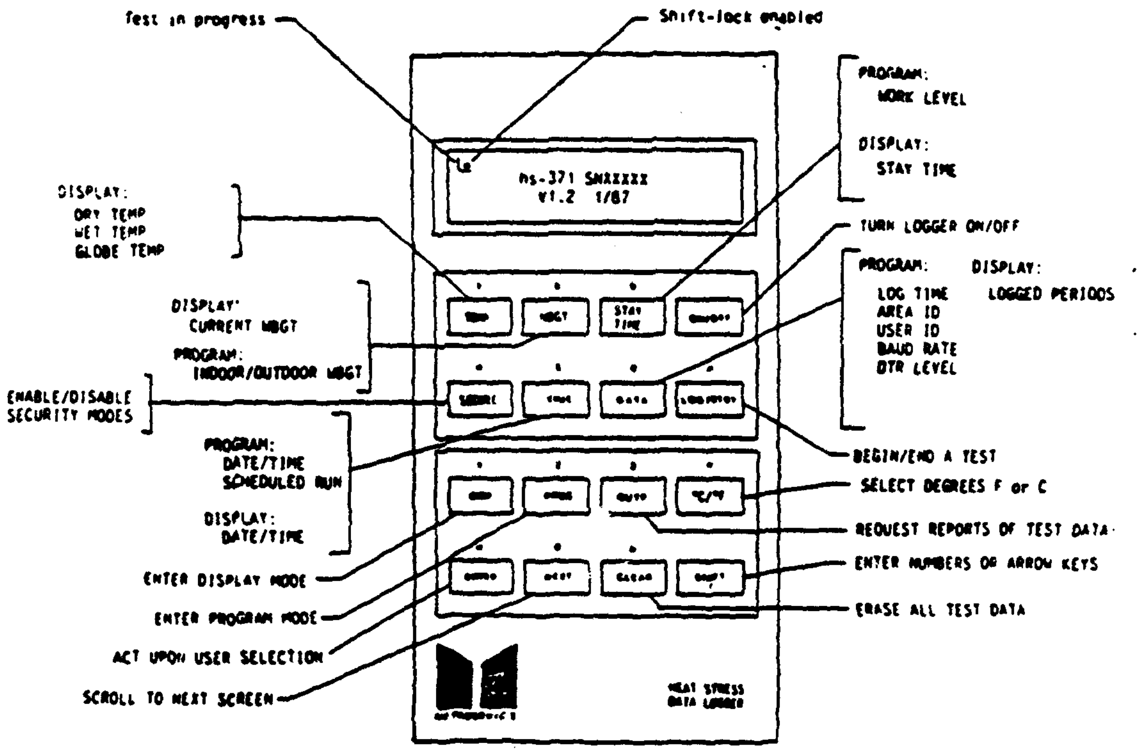
Weight (including sensors): 5 lbs. 10 oz. (1.7 kg)

Specifications subject to change without notice.

METROSONICS

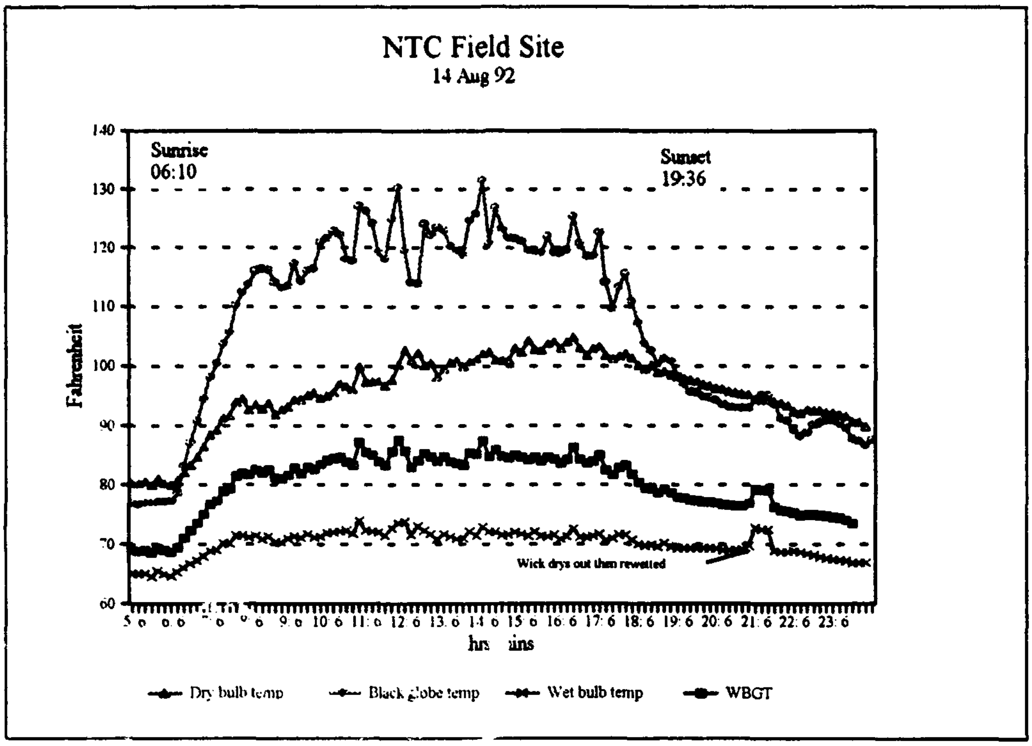
-27-

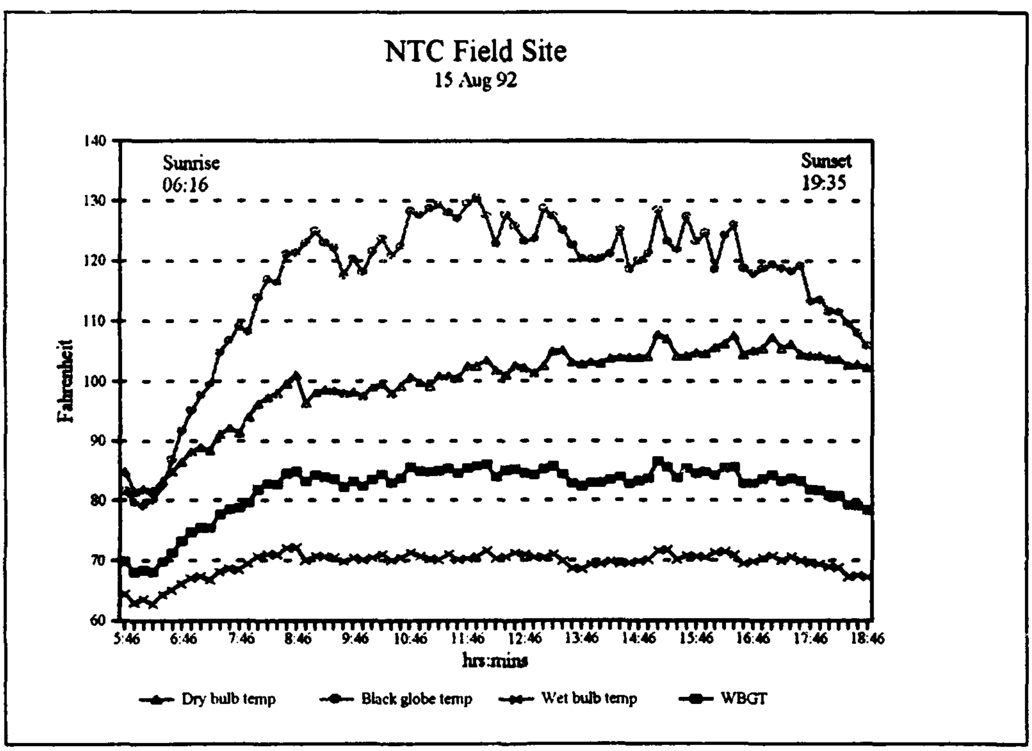
MODE KEY	FUNCTION KEY	RESULT
DISP	TEMP	View current DB and WB temperatures View current Globe temperature
	WBGT	View current WBGT
	STAY TIME	View current stay time View average stay time
	TIME	View current date and time
	DATA	View logged time history data
OUTP	-none-	Produce ASCII output reports suitable for presentation, or a hi-speed data dump

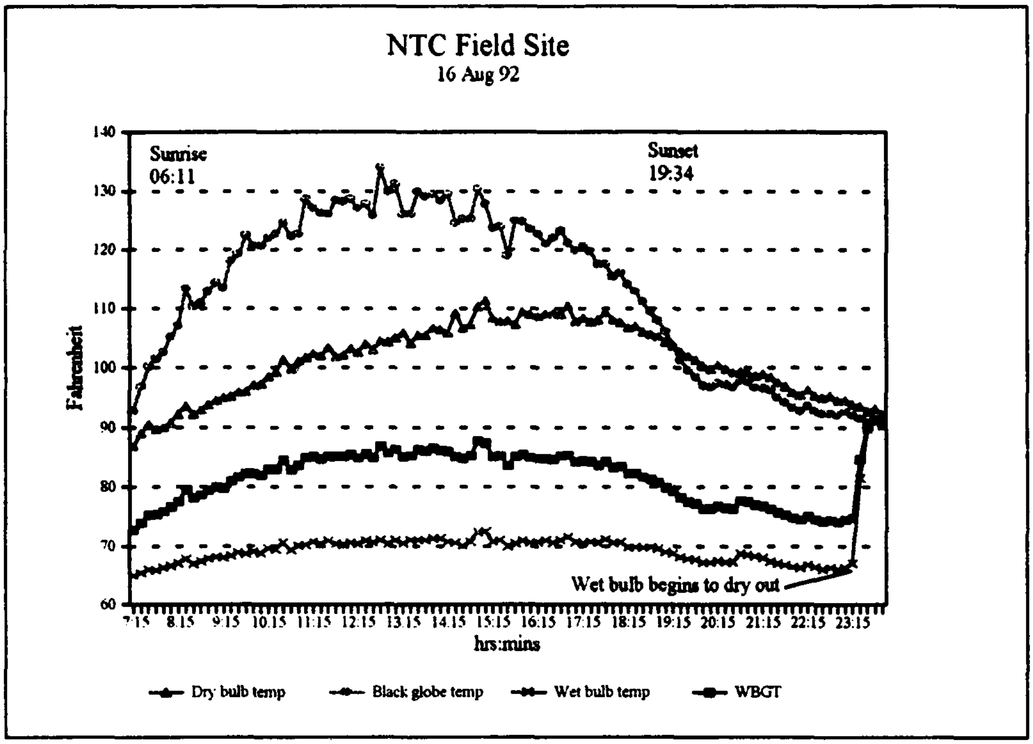


APPENDIX C

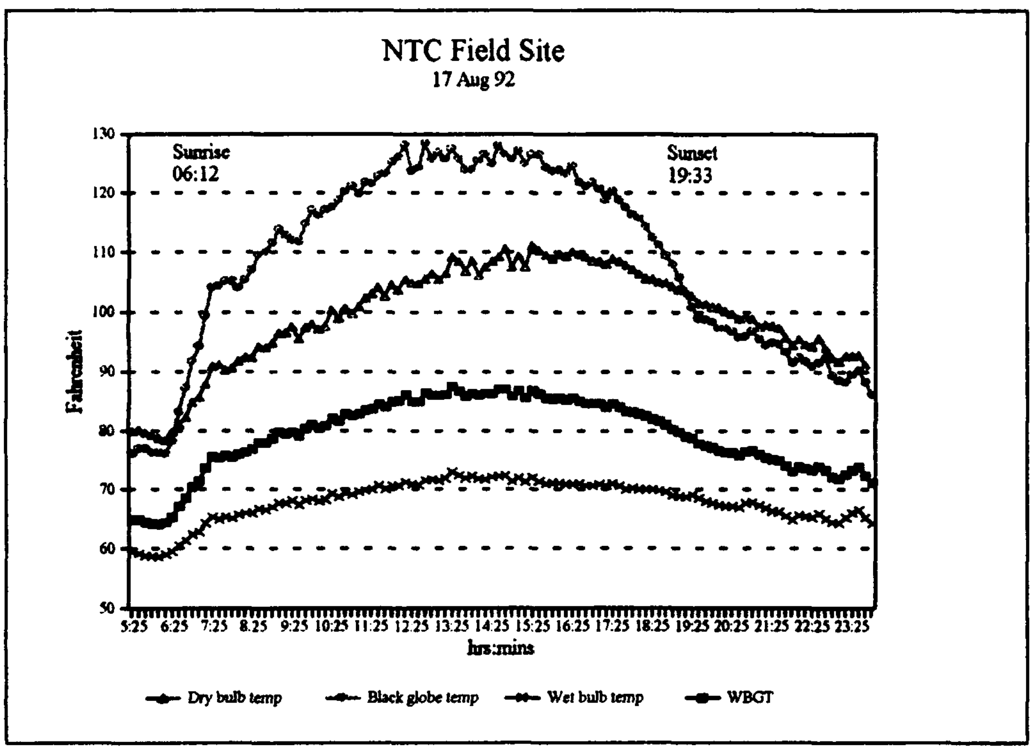
WBGT graphs for 14-19 Aug 92 at various NTC field sites



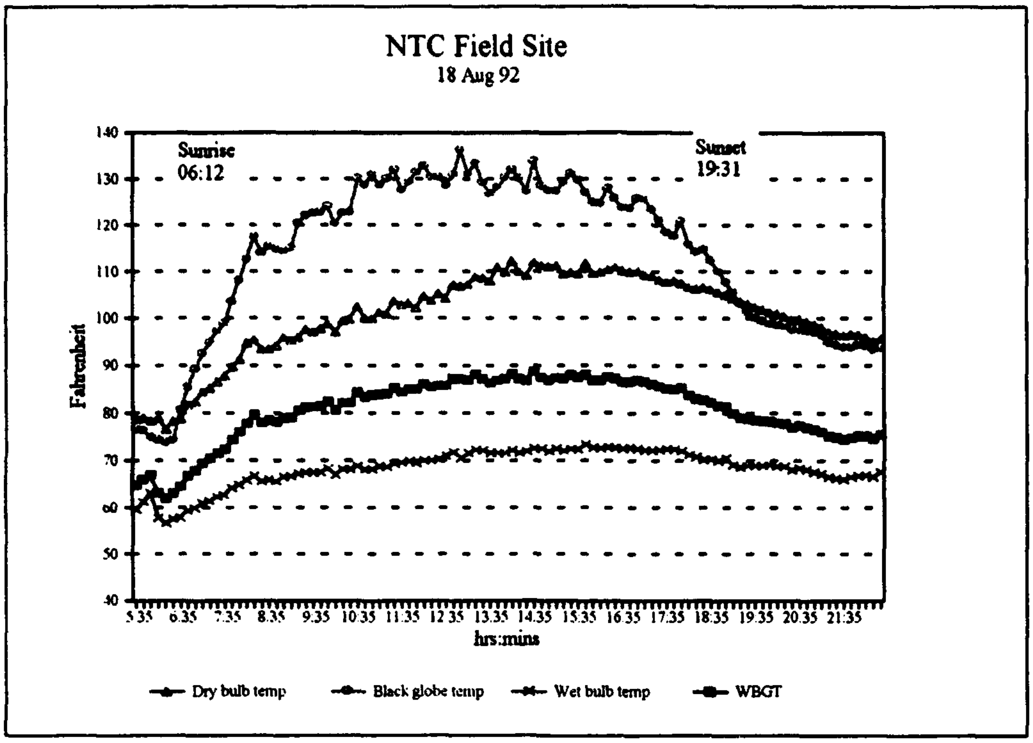


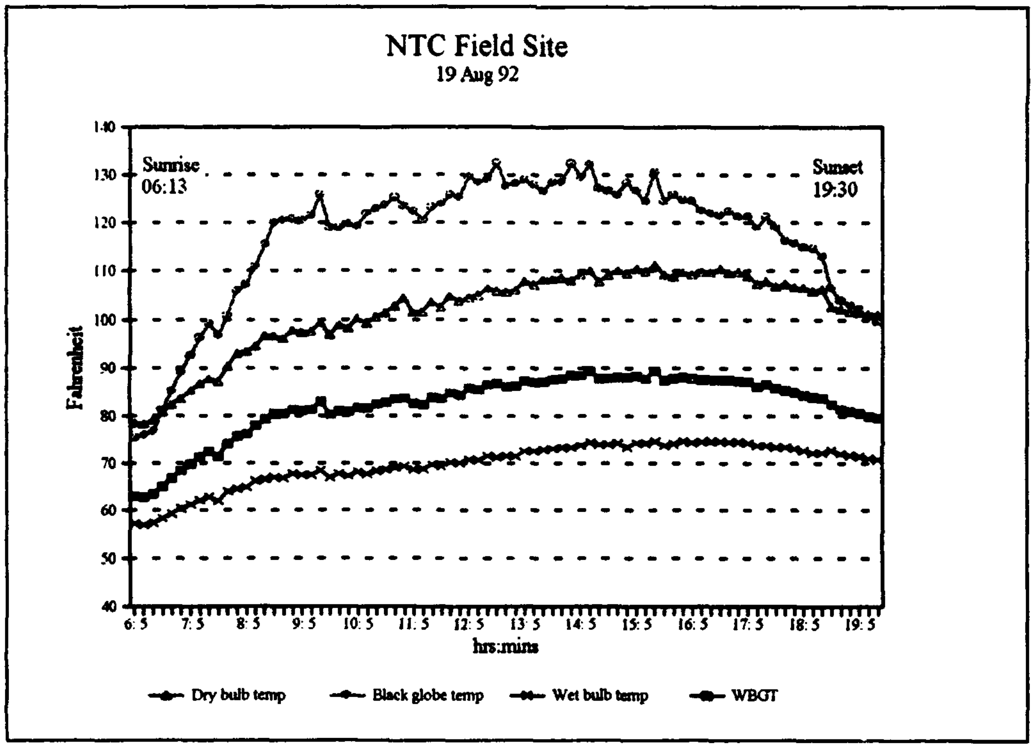


NTC Field Site
16 Aug 92
Sunrise
06:11
Sunset
19:34
Fahrenheit
140
130
120
110
100
90
80
70
60
Wet bulb begins to dry out
7:15 8:15 9:15 10:15 11:15 12:15 13:15 14:15 15:15 16:15 17:15 18:15 19:15 20:15 21:15 22:15 23:15
hrs:mins
Dry bulb temp
Black globe temp
Wet bulb temp
WBGT



NTC Field Site
17 Aug 92
Sunrise
06:12
Sunset
19:33
Fahrenheit
130
120
110
100
90
80
70
60
50
5:25 6:25 7:25 8:25 9:25 10:25 11:25 12:25 13:25 14:25 15:25 16:25 17:25 18:25 19:25 20:25 21:25 22:25 23:25
hrs:mins
Dry bulb temp
Black globe temp
Wet bulb temp
WBGT


NTC Field Site
18 Aug 92
Sunrise 06:12
Sunset 19:31
Fahrenheit
hrs:mins
Dry bulb temp
Black globe temp
Wet bulb temp
WBGT


NTC Field Site
19 Aug 92
Sunrise 06:13
Sunset 19:30
Fahrenheit
hrs:mins
Dry bulb temp
Black globe temp
Wet bulb temp
WBGT

APPENDIX D

Daily Brigade Activities and Heat Stress Casualties

	C Med	24 ID ATLS Tent	Preventive Medicine Activity					Estimated	
	#	#	Midday temps in F				Heat stress	Activity	Brigade activities
August	Sick call	Heat illness	Wb	Bg	Db	WBGT	Category	Level	General description
3	43	7	74	139	114	91	5	1	Dust bowl bivouac
4	58	10	69	108	94	79.3	1	1	
5	52	2	69	132	98	84.5	2	1	
6	54	4	69	132	103	85	3	1	
7	57	5	67	120	97	80.6	1	3	
8	16	0	70	121	103	83.5	2	2	Convoy to 1st field site
9	15	4	70	134	102	86	3	5	1 TF force on force; 2nd TF live fire
10	32	8	67	112	97	79	1	5	
11	27	13	75	132	114	90.3	5	5	
12	31	6	74	134	110	89.6	4	4	
13	29	3	71	126	97	84.6	2	3	AARs, maintenance, and admin
14	14	5	76	127	99	88.5	4	5	2nd TF force on force; 1st TF live fire
15	19	6	73	128	102	86.9	3	5	
16	22	9	73	133	103	88	4	5	
17	20	3	72	132	109	87.7	3	3	
18	11	2	73	140	114	90.5	5	4	AARs, maintenance, and admin
19	20	3	72	140	110	89.4	4	-	Brigade defends
20	-	-	70	133	109	86.5	3	-	Prepare for brigade force on force
21	-	-	68	123	99	82.1	2	-	Movement to contact
22	-	-	-	-	-	-	-	-	Brigade force on force
23	-	-	-	-	-	-	-	-	End of exercise move back to Dust Bowl

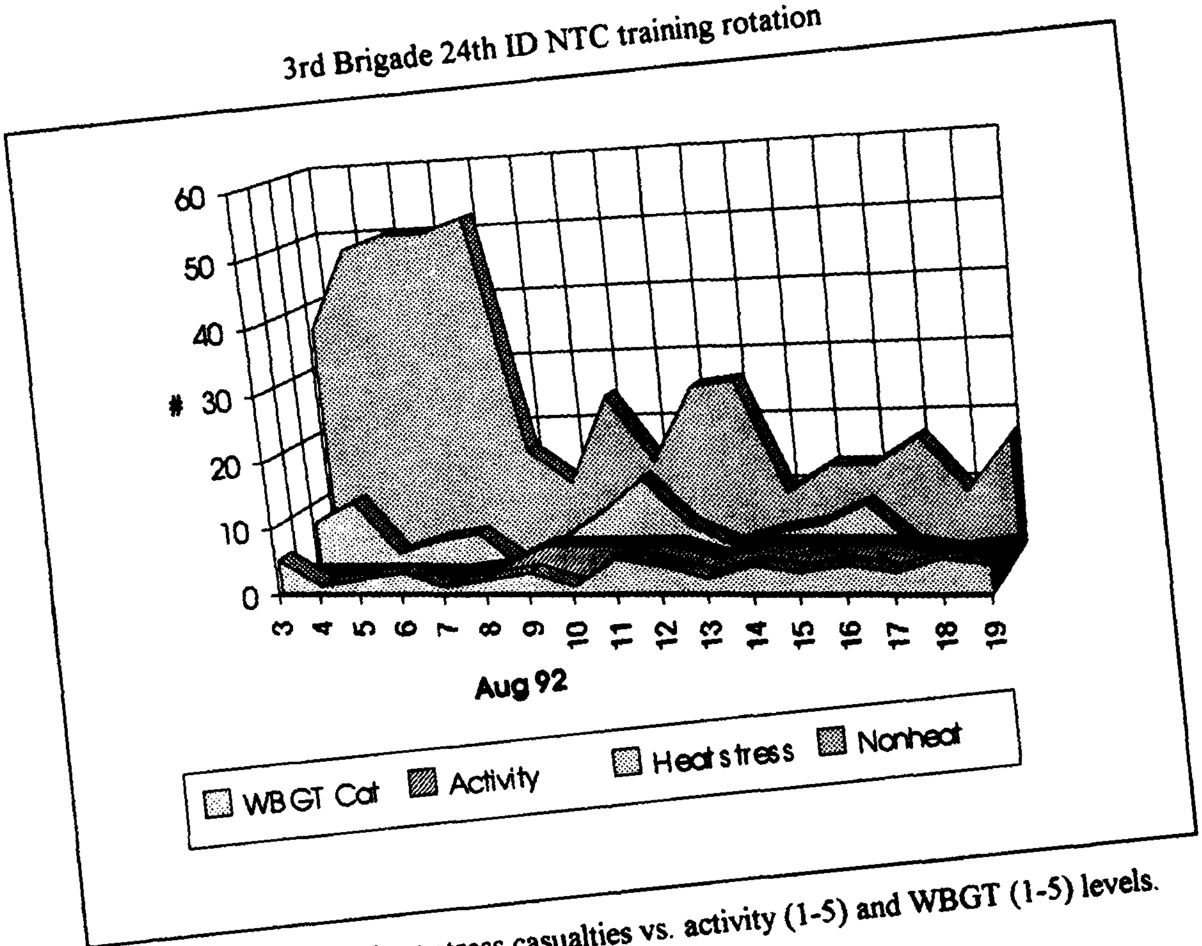
* AAR : After Action Report   ATLS Tent = treatment tent   TF= brigade task force

	# Sick call	# Heat illness		
Total ->	520	90		Baseline # of troops ~ 4200
Mean per day-->	30.6	5.3	20.0%	Incidence: 90cases/(4200*17days)= 1.2 cases per 1,000 troops per day
Std D -->	16.2	3.3	13.2%	

	Wb	Bg	Db	WBGT	WBGT Category
Means -->	71.4	129.0	104.3	86.2	3.1
Std D -->	2.6	7.5	6.0	3.3	1.2

Category	Heat Stress Frequency	Percent
1	3	15.78947
2	4	21.05263
3	5	26.31579
4	4	21.05263
5	3	15.78947
		100.00

3rd Brigade 24th ID NTC training rotation



Heat stress and nonheat stress casualties vs. activity (1-5) and WBGT (1-5) levels.

CORRELATION ANALYSIS

Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 17

	SICK	HEAT	WBGT	WBGT_CAT	ACTIVITY
SICK	1.00000 0.0	0.37339 0.1399	-0.43041 0.0846	-0.46163 0.0621	-0.58918 0.0128
HEAT	0.37339 0.1399	1.00000 0.0	0.07636 0.7708	0.11245 0.6674	0.27508 0.2853
WBGT	-0.43041 0.0846	0.07636 0.7708	1.00000 0.0	0.98020 0.0001	0.29146 0.2564

Sick = total # sick
Heat = total # heat stress casualties
WBGT = noontime WBGT
WBGT_CAT = noontime heat stress category
ACTIVITY = estimate of brigade's average activity level

Table 1 : Correlation of heat stress casualties with same day WBGT

CORRELATION ANALYSIS

Spearman Correlation Coefficients / Prob > |R| under Ho: Rho=0 / N = 16

	SICK_2	HEAT_2	WBGT_1	CAT_1	ACT_1
SICK_2	1.00000 0.0	0.12435 0.6463	-0.06770 0.8033	-0.04352 0.8729	-0.56975 0.0212
HEAT_2	0.12435 0.6463	1.00000 0.0	0.14201 0.5998	0.20364 0.4494	0.27509 0.3025
WBGT_1	-0.06770 0.8033	0.14201 0.5998	1.00000 0.0	0.98070 0.0001	0.31825 0.2296

Sick_2 = total # sick
Heat_2 = total # heat stress casualties
WBGT_1 = noontime WBGT on preceeding day
CAT_1 = noontime heat stress category on preceeding day
ACT_1 = estimate of brigade's average overall activity level for preceeding day

Table 2: Correlation of heat stress casualties with previous day WBGT

APPENDIX E

Characteristics of Heat Stress Casualties Evacuated to the Ft. Irwin Hospital (WACH)

3rd Brigade 24th ID Heat Stress Casualties Evacuated Directly from the Field to the WACH ER

	Case #:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Age:	20	20	27	19	21	19	19	27	30	23	19	26	21	24		22
	Gender (1=M 2=F):	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Rank (E- #):	4	2		3	3	1	2	4	7	4	2	4	3	4	4	4
	Unit:	Infantry	Artillery	CSS	Engineer	Infantry	Infantry	CSS	CSS	CSS	Infantry	Infantry	Infantry	Aviation	CSS	Infantry	CS
	Activity:	Carrying ruck							Setting up TOC 3	resting in tent					MOPP4 for 2 hrs this AM		
	# previous heat illnesses:	0	2	0	0	0			1	3	0	0				3	
	[illegible] Aug 92:	11	8	10	10	10	10	10	16	18	13	10	10	10	16	21	
Field -->	Time in:	1315		1300			1300								1315		
	Sx 1:	LOC		H/A			no urine x 12 hrs		cramps						syncope		syncope
	Sx 2:			cramps			cough		H/A						cramps		dizziness
	Sx 3:			emesis					emesis						nausea		weak
	Temp:	102		100.6			98.2		101	103					101		
	HR supine:	102		81			60		88						96		
	del HR:						20		12								
	PE finding 1:			confused			pale skin		mod distress o/w wnl						lethargic		
	PE finding 2:						fatigue										
	PE finding 3:						red eyes										
	Dx 1:	Heat stroke		heat exhaustion			dehydration		heat cramps						heat injury		
	Dx 2:			dehydration			bronchitis		s/o electrolyte abn								
	Lts FL:	3		5			5		4		1					4	2
	Time out:	1315		1800													
	Last temp:																
ER -->	Time in:	1400	1923	1636	1900	1515	1835	1510	1347	1510	1940	1440	1425	1519	1348	1725	1927
	Sx 1:	SOB	fatigue		weakness		dizziness		cramps	dizziness	weakness				cramps		syncope
	Sx 2:	H/A	dizziness		dizzy		H/A		H/A	weakness	dizziness				nausea		dizziness
	Sx 3:	Abd cramps H/A							emesis								weak
	Temp:	99	100	99.4		99.6	99.6	99	99.3	99.5	100.2	98.6		99.2	99.9	98	97.7
	HR supine:	81	88	88	71	86	83	100	90	76	76	107		90	92	75	70
	del HR:			2	10		-15				20						
	PE finding 1:			wnl	wnl	wnl	wnl	wnl	wnl	dry warm skin	wnl	glasgow 14	lethargic	wnl	lethargic	[illegible]	glasgow 13
	PE finding 2:											CP spasms	glasgow 13			wnl	skin damp & warm
	PE finding 3:												confused, withdraws from pain				ECG wnl
ER Lab -->	Sp gr:		1.25	1.3		1.02	1.02	1.025	1.01		1.015	1.030	1.025	1.020			1.020
	Ketones:		0	40		80		15				40	40	40			
	Na:		140	142	147	140	143	144	139		140	142		147	140		140
	K:		4	3.8	4.5	3.6	3.7	3.9	3.7		3.4	4		3.7	3.6		3.9
	Cl:		105	106	107	105	104	107	103		100	104		108	105		111
	Bicarb:		25	21	23	23	24	21				16		22			25
	Glucose:		104	87	113	90	88	83	81		101	81		80	89		100
	BUN:		11	17	10	9	9	18	20		9	22		16	10		4
	Creat:		0.7	1	1.1	0.9	1.1	1	1.7		1.1	1.2		1.2	1.1		1.3
	Hct:		47.4	41.7	40.4	40.9	40.1	39.3	43.3		41.2	39.8	44.4	42	40		40
																	LFTs wnl
	Dx 1:	heat exhaustion	heat exhaustion	heat exhaustion	heat exhaustion	heat exhaustion	heat exhaustion	heat exhaustion	heat exhaustion	heat sensitivity	heat exhaustion	heat stroke	heat stroke	heat stroke	heat exhaustion	heat intolerance	heat exhaustion
	Dx 2:		dehydration						dehydration						dehydration		heat syncope
	Lts FL:	3	3				2	3			1				3	2	2
	Time out:	1015	2220				2200		1030	1600	2125	1722		1748			
	Days quarters:	1	1	2	2		1	1	1	1	2	1	1	1	2		1

APPENDIX F

Photographs of the NTC Training Environment

This laeger area is where the Brigade soldiers bivouacked prior to, and after, the field exercises. Note that the structures provide shade from direct overhead sunlight and are otherwise open on all sides to maximize ventilation. Soldiers set up two-man standard issue pup-tents under these structures. This illustrates that simple structures can provide protection from excess solar radiation.

This large fabric shade structure was located at the North end of the Dust Bowl bivouac area. In front and middle are large truck/train rectangular shipping containers. This fabric shade structure is called a Large Area Shade System (LASS) developed by NRDEC's Tentage and Organizational Equipment Division. It covers a 210 feet by 210 feet area (one acre) and is 18 feet high. It is designed to provide solar protection for field depots, casualty collection areas and POW sites. Thirty such structures were deployed in support of Operation Desert Shield/Storm. It's dry weight is 26,000 pounds. It is made of a knitted open mesh fabric and therefore does not provide rain protection. The weight of water, ice, or snow accumulation on the broad flat roof will cause the LASS to collapse, therefore it is intended only for use in dry hot climates. The fabric shell is supported by steel square tubing and cables. Nominally it can be set up in eighty hours by a team of ten individuals.

Other fabric shade structures in various stages of development and testing by the Tentage and Organizational Equipment Division of the US Army Natick RD&E Center include the Modular Ammunition Solar Shade (MASS), Solar Hex Liner (HEX) designed to be attached to the underside of camouflage netting, and a T-shaped Mil-Van shade cover.

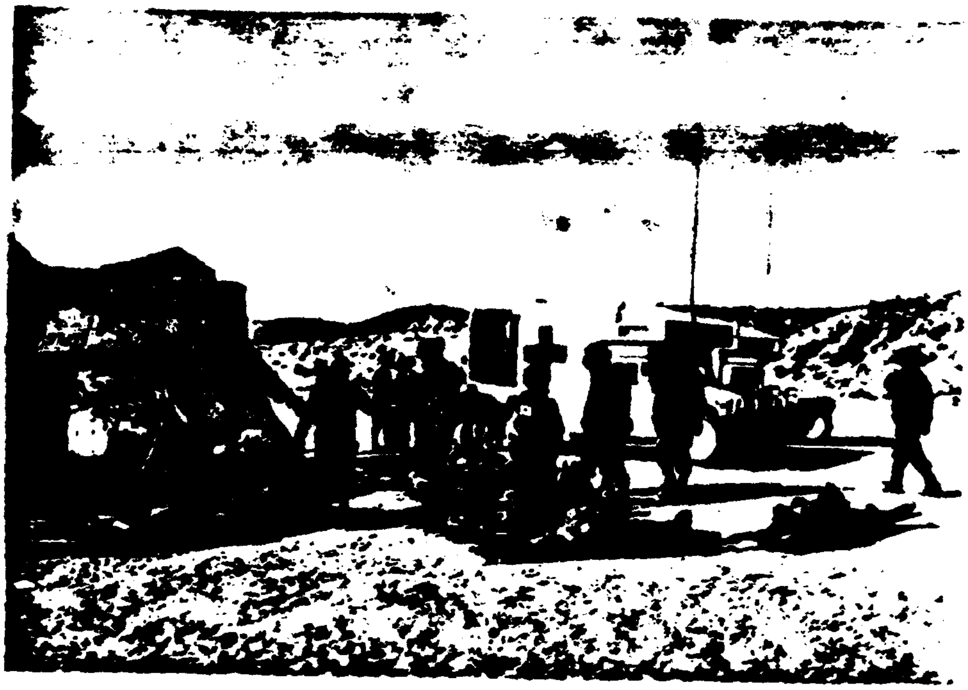
This is a photograph of the Medical Company water trailer (Water Buffalo). It is the usual method of providing bulk water to platoon and company units. It's capacity is 400 gallons (1514 liters). Three tablespoons (field messkit spoonfuls) or twenty two ampules of calcium hypochlorite mixed in a half canteen cup of water are usually required to chlorinate a full trailer. The chlorine level must be checked after ten minutes. Additional calcium hypochlorite may need to be added to bring the chlorine levels up to the recommended 5 ppm. An additional twenty minute contact time is require before the water is allowed to be consumed. Hot weather may cause the residual chlorine to dissipate more rapidly than usual.

According to FM 21-10-1 (Unit Field Sanitation Team), in hot weather environment, the recommended rate of potable water distribution is 3-6 gallons (11-23 liters) per soldier per day. If improvised showers are permitted, the water allocation should be increased to at least 15 gallons (57 liters) per person per day.

In circumstances where solar radiation is intense and globe temperatures are high, water trailers and Lyster bags should be situated under natural or artificial shade. During this NTC

rotation, even with solar protection, water from the Medical Company water trailer during the day was 100-105 °F.

Pallets of ice were distributed on a daily basis by brigade supply at a rate, initially, of 13 lbs/soldier/day but later increased to 17 lbs/soldier/day. Priority for ice supply went to the combat units. The ice was usually dumped into various water containers to cool the otherwise unpalatably warm temperatures of the available drinking water. During actual deployments to foreign countries ice supplies must be obtained from sources that have been approved by Army inspection teams (Preventive Medicine or Veterinary) to ensure that the ice is made from potable water and that contamination does not occur during storage and transportation by indigenous contractors.



These are simulated casualties triaged and lined up for loading into the field ambulances for evacuation. Although these simulated casualties lay in the direct sun for only a brief period of time this photo illustrates that real casualties must be protected from solar radiation. These litter patients are also shielding their eyes from the overhead sun. Any patients with ocular injuries or impaired mental status must be protected from gazing directly into the sun to prevent retinal burns and solar keratitis. This is an additional reason to keep patients under shade.

Carrying litter patients is arduous work that can rapidly lead to exhaustion and heat injury if work rest cycles are not utilized. Litter teams must be rotated on a frequent basis if large numbers of casualties are continuously being moved about the treatment area. Team leaders must ensure that the liter team members drink ample water. The Medical Company commander exhibited excellent leadership in obtaining additional liter teams from surrounding brigade combat service support units prior to the several large (100+ simulated casualties) mass casualty scenarios that occurred during this training cycle.

This photograph illustrates the large amounts of dust that may be kicked up by an approaching helicopter in areas of sand and loose dirt. This effect can be sufficiently severe to cause a "brown out" for helicopter crews with loss of visibility and increased hazard of landing accidents and rotor strikes. The medical helicopter evacuation landing area should be located in areas that minimize this dangerous effect of rotor downwash.

Helicopter crews must monitored by their flight surgeons for the potential adverse effects of heat stress. It has been demonstrated (From, et al., 1991) that helicopter cockpit WBGT can often exceed the ambient WBGT. This is particularly true during ground standby and nap of the earth flying. Much of this effect has been attributed to the "greenhouse" effect whereby cockpit windows transparent to solar radiation in the visible spectrum retain heat because they are concomitantly relatively opaque to infrared radiation emanating from the heated surfaces within the cockpit. Cockpit WBGT increases also because evaporative water losses from crew members results in elevated humidity and an associated rise in wet bulb temperature. Cumulative heat stress over several days may lead to sudden decompensation of the aviator (Mitchell,1991). A less obvious side effect of heat stress in the aviator is diminution in G_z tolerance due to thermoregulatory redistribution of central blood volume to the skin (Alan and Crossley, 1972).

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